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Sewer conduits –

aids to decision-making with regard to materials

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Sewer conduits – aids to decision-making when choosing materials

The loads and stresses on sewer conduits and the materials used are liable to change, increase or occur for the first time in the time that elapses between planning, construction and operation.

Calculating and estimating these and ensuring adequate margins in planning are exacting tasks. On the other hand, ascertaining afterwards that changes in the operating conditions in a sewer conduit have taken place is relatively easy. Aids to decision making are described which relate to a holistic assessment of pipe materials with the main point of emphasis on calculating the possible hazards arising from biogenic sulphuric acid corrosion.

Changes in the drainage flow characteristics of the conduits are of major importance. Full testing of drainage flow characteristics, resistance to chemical action, static stress analysis, high pressure flushing strength, corrosion and economic viability represents an indispensable planning instrument for sustainable decisions regarding pipe materials. Planning involves taking technical and commercial responsibility for the decisions that are made.

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Introduction

Biogenic sulphuric acid corrosion in sewage systems is a problem which has been known of for many years. This situation has been aggravated by the recent significant reduction in water consumption and the related lower flow of sewage waters. Information is increasing on corrosion damage and odour problems.

Planning instruments are available for new construction work so as to preventively act against these loads. Mixed water and waste water conduits are both affected in the same way. The same hydraulic boundary conditions apply to the transport of domestic, commercial and industrial effluent in terms of gravity drainage. The water in the sewage is available as the transport medium. The necessary hydraulic boundary conditions must be observed to ensure a safe and sediment-free operation. In choosing the raw material, the knowledge of and experience gained in flow and transportation processes as well as the interaction of drainage flows and pipe materials are significant. To avoid and eliminate deposits, the flow processes are supported as necessary by regular maintenance of the conduits using high-pressure cleaners.
It is fundamentally assumed that the sewer conduits are structures which have been installed for long-term use. The expected long life of the sewer conduit infrastructure can, however, only be achieved if all the relevant quantitative and qualitative influencing variables are taken into account during the technical and economic evaluation of the project in the planning phase. This simultaneously ensures that public funds are handled with care and foresight. In connection with the significant reduction in the quantities of sewer to be drained the assessment of possible corrosion caused by the effluent is gaining greater importance. The planning instrument available for this is the calculation of the Z value according to Pomeroy.

Drainage flow

Quantity, arrival pattern and characteristics of sewage
The water consumption per resident both in households and small commercial operations has stabilized in recent years at 128 to 130 l per resident per day [1]. It is worth noting that this is an average water consumption over the whole fresh water consumption in Germany. The corrected figures from the sewage treatment plants and water supply companies for the actual consumption and drainage flows of household and commercial sewage permit the conclusion that a value of 128 l/R does not correspond with the actual hydraulic load. Consumption values of 60 to 90 l/R are more realistic [1.16]. This is not only valid for country areas in which the average values are always lower. Also of interest are the charts showing the consumption variations over the course of a day according to the catchment area [2]. The charts in **Fig. 1** clearly show that it is indeed in the country and in thinly-populated areas that consumption peaks and times alternate with very low water consumption with the related significant variations in the waste water flow.

Quantity and arrival pattern of rainwater
The dimensioning of the mixed water conduits for rainwater drainage is carried out according to the authoritative rainfall figures, the topography and the amount of building development. Experience has shown that over two-thirds of the year the freshwater conduits only serve to transport waste water. As a result of this it follows that mixed water conduits act as waste water drains for the longest period each year.

Sewage water flows
With the issue of the ATV working paper A110 entitled "Guidelines for the hydraulic dimensioning and evidence of capacity for sewer conduits and pipelines" in 1988 [3] limits were shown for the first time for sediment-free operation. "Critical speeds and inclines" are given related to the nominal widths based on an operating roughness of K_b = 1.0 mm and a volume

concentration of precipitable solids of C_t =

0.05%. **Table 1** shows an excerpt from ATV A110, Table 12. These values must be increased by around 10% in the partial filling range h/p = 0.1 to 0.3 µm. By maintaining these limiting speeds a contribution can be made during dimensioning to the avoidance of harmful sedimentation in the drainage and operation of the sewage network. The showing of these limiting speeds is only one aspect in the dimensioning of sewer conduits and pipes. If sedimentation does occur and if it has to be removed then it is also necessary to consider the loads caused by high-pressure rinsing.

The principles of the decision on the pipe material

The requirements can be described in summary as follows: Permanently leak-proof, hydraulically smooth, resistant to corrosion, interruption-free drainage under all operating conditions, easy to maintain and a long service life.

These principles must be taken into account and evaluated during the design work. The decisive mechanical, chemical and biological loads must be determined, their effects on the calculation established as far as possible and checked over the whole period during which the sewer will be in operation. It is only after the fulfilment of all the requirements established from the sewage operation that the question of carrying out the building work can be clarified.

External loads on the pipe material

The external loads and the resulting stresses as well as the possible related types of damage can be sub-divided as follows [4.5]:

* **Mechanical loads**: Earth load, traffic load, buoyancy, temperature, subsidences, drainage flow. *Damage:* Cracks, deformation, leaks, abrasion.
* **Chemical loads**: Acids, alkalis, aggressive substances in the sewage. *Damage:* Decomposition, deformation, corrosion in the discharge area.
* **Biological loads**: Organic substances in sewage. *Damage:* Corrosion due to biogenic sulphuric acid in the pipe crown **(Fig. 2)**

The decision on the pipe material to be used must be made on the basis of the following evidence due to the different loads:

* The hydraulic dimensioning taking account of sedimentation
* Structural evidence of the carrying capacity of the pipe
* Chemical evidence on the reaction of sewage / soil / groundwater / pipe material
* Maintenance evidence on the resistance to high-pressure cleaning of the pipe material
* Biological evidence of biogenic sulphuric acid corrosion.

Evidence

Evidence is a component of the planning operation. In the event of changes within the scope of the contract-awarding procedure and execution of the construction work, such evidence must always be checked and recreated as necessary.

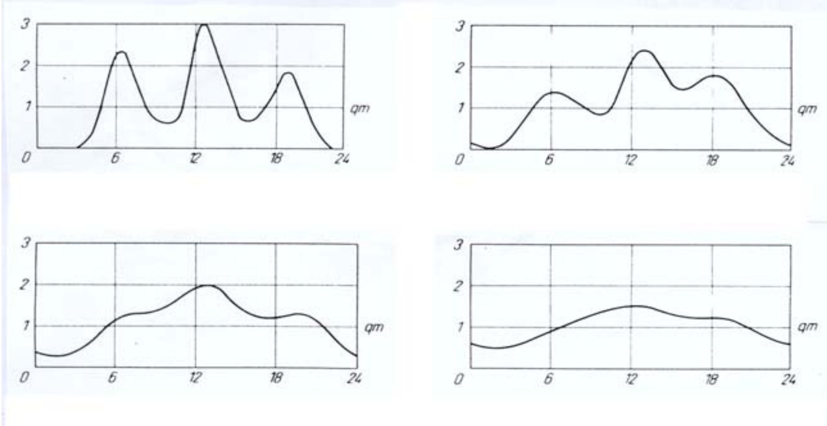

Fig. 1: Volume of sewage from various catchment areas (3)

Hydraulic evidence of sedimentation-free drainage flow

For the hydraulic evidence, reference is made to the ATV working paper A110 in which the minimum flow speeds are shown with respect to the nominal widths. The quantity of sewage water must be considered critically against the background of water saving, low-consumption household devices and the high level of household sanitary fittings. Gravity drainage systems require water to transport away the sewage ingredients. Organic sedimenttation causes odours which can lead to significant nuisance to the local residents and the attendant complaints. Odour problems do not simply arise in connection with the drainage of sewage with high organic loads. Even so-called "normal household sewage" can become problematical in the event of insufficient flow conditions.

Structural evidence

The structural evidence concerning sewer conduits and pipes is furnished on the basis of the ATV working paper A127 "Guidelines for structural calculations for drainage conduits and pipes" [6]. This guideline provides a uniform calculating

	V_{gr}	I_{crit}
Diameter range	Limiting speed m/s	Critical gradient %o
DN 200	0,50	2,04
DN 250	0,52	1,63
DN 300	0,56	1,51
DN 400	0,67	1,45
DN 500	0,76	1,40
DN 600	0,84	1,37
DN 800	0,98	1,31
DN 1000	1,12	1,26

Table 1: Excerpt from ATV working paper A 110, Table 12

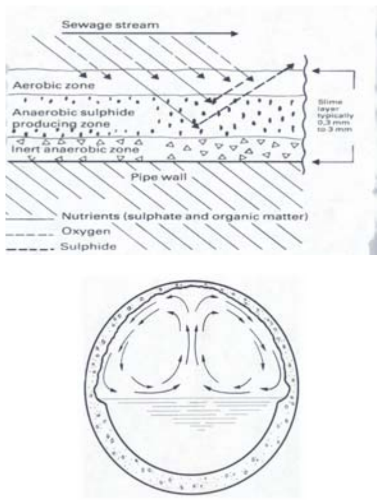

Fig. 2: Basic structure of biogenic sulphuric acid corrosion

method for the pipe materials used in sewage technology. The Technical Regulation for pipe installation is DIN EN 1610 [7]. In this case the structural evidence is required without exception before starting the work.

Within the scope of the planning a general structural calculation [8] can be used as initial information on the capacity of the pipe-soil system (Fig. 3), whilst the individual evidence is then obtained within the scope of detailed building plans. To retain the boundary conditions specified by the planner for the installation of the pipe, limiting values can be specified amongst other things.

The combined effect of A127 and DIN EN 1610 is strengthened with the revision of the ATV working paper A139 [9], which is available at present in draft form.

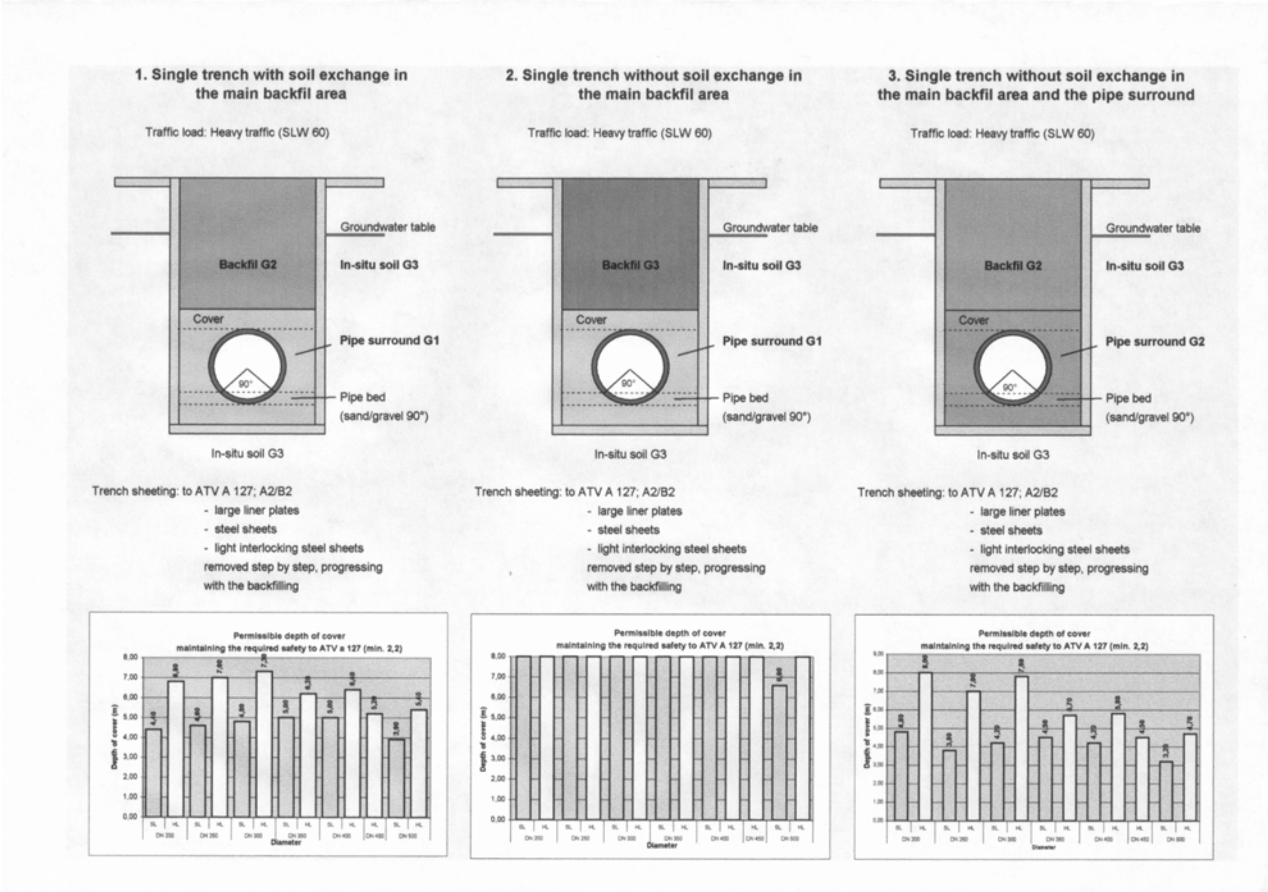

Fig. 3: Framework structural analysis for the initial information on the load bearing capacity of the pipe/soil system

Evidence of chemical resistance
The appropriate pipe standards and resistance lists for the sealing materials should be included for the evidence of the suitability of the pipe material with respect to sewage waters containing chemical and aggressive ingredients. This test can take place comprehensibly and verifiably on the basis of the technical regulations. The valid base standard for pipe materials
EN 476 [10] offers a suitable basis for the preparation of an object-related and comprehensible checklist for establishing the suitability of the individual materials and products. Additional application-related influences can be taken into account with the help of assessment codes [11] (Fig. 4).

Evidence of the resistance to high pressure rinsing
Evidence of the suitability of the pipe material with respect to loads caused by conduit maintenance is provided today through the testing of the resistance to the loads caused by high pressure cleaning. The proposed European Standard which is currently being prepared in the form of CEN TC 165/WG1/TG5 envisages that pipe materials must show evidence of their suitability for continuous (cleaning) and the stresses involved during the removal of sediment (deblocking) [12].
Comprehensive test results have been published by H R Steiner, Zürich [13-15].

Evidence against biogenic sulphuric acid corrosion
The evidence of suitability or the demonstration of possible risks to the pipe material from biological attack is provided by estimation of the biogenic sulphuric acid corrosion. Very often this problem is not noticed until the operation period or when damage to the sewage network is found.

Material	Hydraulic (10)	Resistance (20)	Structural strength (15)	Installation (10)	Tightness (20)	Product range (15)	Environment (10)	Total valuation
Concrete								
Reinforced concrete								
Fibre cement								
Polymer concrete								
PVC								
PE								
PP								
GRP								
Ductile iron								
Vitrified clay								

Fig. 4: Example of an assessment matrix for pipe materials

Fig. 5: Biogenic sulphuric acid corrosion in a manhole

On top of this, the drainage flow is changed by means of significantly changed boundary conditions. The existing sewage network must then be able to deal with this situation [16-18].

Advice is now given here about the estimation of this risk potential. Starting points are:

* Waste water collector
* Mixed water collectors
* Confluences of pressure lines from individual pumps and pressure drainage systems into the gravity network
* Collectors with significantly reduced proportion of waste water
* Waste water with long transport times in the sewage network

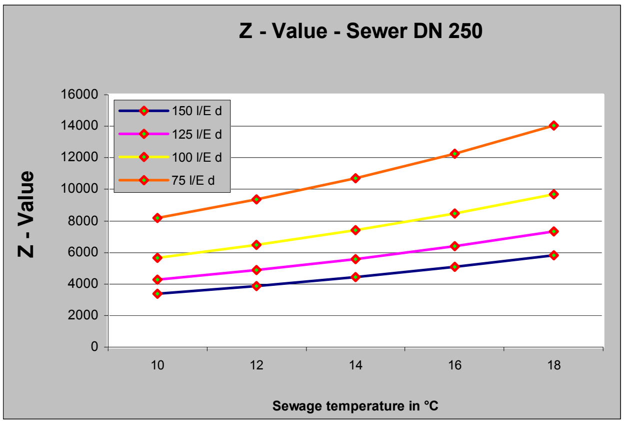

Fig. 6: Z-values for a DN 250 sewer varying with the sewage temperature

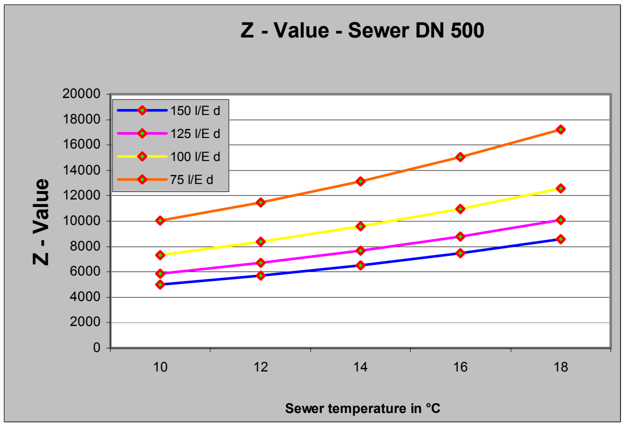

Fig. 7: Z-values for a DN 250 sewer varying with the sewage temperature

- * Collectors, designed for the future, but having today a low discharge
- * Sewers with low gradients
- * Sewage collected from particular industrial and commercial operations as well as household treatment plants .

The ATV working paper M168 [19] describes the different forms of corrosion, gives advice on planning, construction and operation and supports the practical selection of suitable materials.

Biogenic sulphuric acid corrosion attacks cement-bound materials and those with cement linings. **Fig. 5** shows an example of the effects of biogenic sulphuric acid corrosion in the form of a corroded shaft. The necessary precondition for biogenic sulphuric acid corrosion is the growth of sulphide. The organic contamination of the sewage water has a decisive effect on this. Sulphide growth is assisted by the sewage temperature, the drainage flow behaviour and the existence of sediment in the sewage network. Also of signify-cance are long transport times for the solids in the sewage and the resulting biological and biochemical processes.

The application of the so-called "Z formula" by Pomeroy [19,20] can be recommended for estimating the potential risk of the sewage with respect to biogenic sulphuric acid corrosion. This is valid for the assessment of waste waters with continuous organic load and links the hydraulic and biological boundary conditions into a common dimensionless variable (Z value):

$$Z = \frac{3 \times BSB_5}{J^{1/2}\,Q^{1/3}} \cdot \frac{U}{b}$$

Where:

BSB_5 = defined as the standard BOD (Biochemical Oxygen Demand) over a period of 5 days at 20°C (BSB_5), multi-plied by the

- temperature factor $1.07^{(T-20)}$ in mg/l
- organic contamination: 60 g BSB_5/E*d
- water consumption: l/E*d

J = Pipeline gradient in %

Q = Discharge in l/s

U/b = Ratio of wetted circumfer-rence to the width of the flow at water level.

The following relationships can be expected for given Z values:

Z > 5000: Hardly any sulphide present Or only in very small con-centrations.

Z ~ 7500: Peak concentration of only a few tenths of a mg/l of dis-solved sulphide can arise. Concrete and masonry can be slightly attacked. Signi-ficant corrosion can some-times be observed in the vicinity of points with high turbulence.

Z ~ 10000: The sulphide concentration is such that odours can increasingly occur. Concrete and masonry can be significantly attacked, especially in the vicinity of points with high turbulence

Z ~ 15000: Occasional distinct odour. Fast attack of concrete parts at points with high turbu-lence can be expected as well as a strong attack at other points. Destruction within 25 years can be ex-pected in the case of a concrete pipe with a wall thickness of 25 mm.

Z ~ 25000: Dissolved sulphide is usually present. Smaller concrete pipes are usually destroyed after 5 to 10 years.

The example calculation shows how the changed waste water flow in existing collectors affects the possible corrosion resulting from biogenic sulphuric acid.

The boundary conditions are:

- * DN: 250 or 500
- * Operating roughness: 1.5 mm
- * Gradient: 5%
- * Residents: 5000
- * Water consumption: Varies from 150 to 75 l/E d

The result of the display (**Figs. 6 and 7**) can be summarized with respect to the Z value as follows:

- * Increasing Z values with de-creasing gradient and increa-sing temperature
- * Increasing Z values with low water consumption under other-wise similar conditions
- * The effect of a reduction in the water consumption is the same as an increase in the tempera-ture of the sewage.

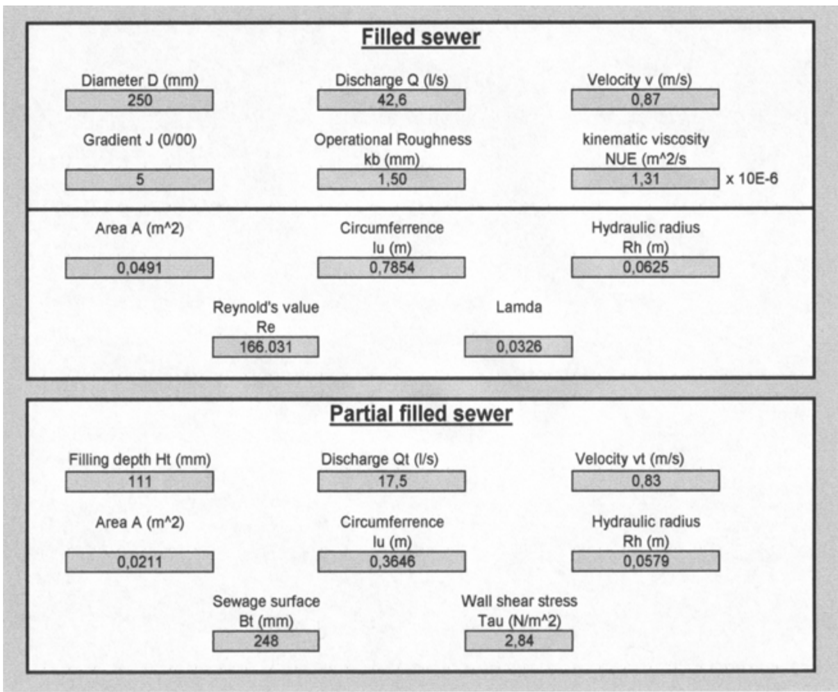

Fig. 8: Printout of full/partial filling

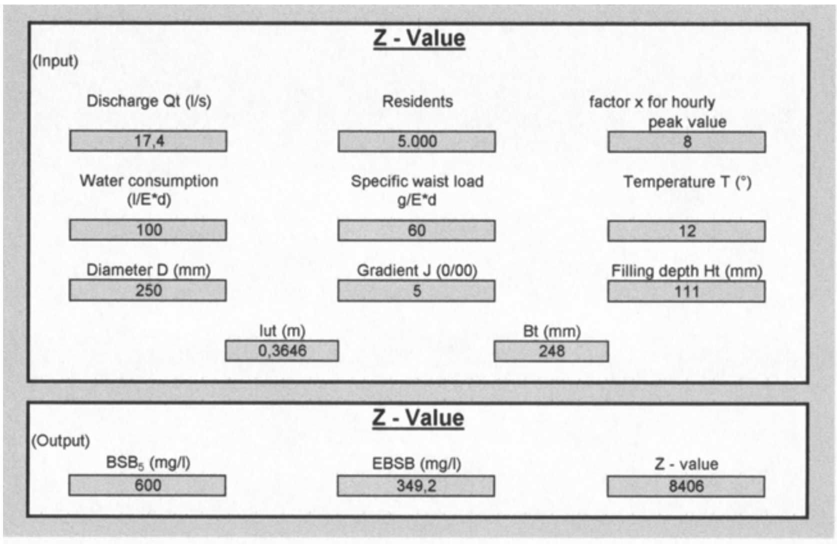

Fig. 9: Printout of Z-value

If Z values are established to be in excess of 7500 it is essential to carry out an accurate calculation of the formation of sulphuric acid and biogenic sulphuric acid corrosion.
The software available [22] (Figs. 8 and 9) permits a rapid and uncomplicated check to be made on the waste water flows to establish any risk to the pipe material from biogenic sulphuric acid corrosion. By linking the Pomeroy calculation to the hydraulic calculation according to ATV A 110, a suitable aid is also provided as evidence of sedimentation-free flow.

Economic evidence

The evidence described above is all based on technical criteria. This is supplemented by the evidence of the economics based on the “Guidelines for carrying out cost comparison calculations” [23] which have existed since 1986 and which were published by the LAWA (Regional Working Party on Water). With this method technical and financial aspects can be combined into one crite-rion. The decision is then objective and comprehensible. The essential input variables for processing sewer construction plans are the execution costs and the service life of the system parts. These are determined by the material properties of the pipe used and the sewage operating practice. Long serving structures contribute significantly to maintaining low sewerage charges.
The application is simplified by using software which also covers the complete area of the problems involved in sewage handling [24]. The work involved with this will certainly be justified by the expected success – viz. the evidence for the efficient and economical use of public funds. The technical and economic evaluation of variant project designs is standard today.

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