SediPipe: Research and guidelines for implementation

24 July 2012

Tauw

SediPipe: Reseach and guidelines for implementation

Excerpt

Responsibility

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1 Introduction

1.1 Introduction

Storm water contains micro-pollutants (e.g. PAHs and heavy metals). These pollutants can have an effect on the quality of the soil, groundwater and surface water.

Cost-effective storm water treatment systems that are easy to implement and maintain in (dense) urban areas are required to mitigate these effects.

These systems are of special interest as they in addition of treatment offer a valuable functionality: they protect the Sustainable Urban Drainage Systems (SUDS) from clogging by fine particles (< 0,06 mm) and sand (> 0,06 mm). They reduce the maintenance efforts and guarantee the investment’s efficiency and durability of infiltration facilities or other SUDS.
One of these products is SediPipe from Fränkische, which is already implemented on some locations in the Netherlands. Various experiments have been done up to now to evaluate the hydraulic performance and treatment capacity of the SediPipe system for storm water treatment by several organizations in Germany.
In the years 2010 and 2011 scaled (1:5) and full size (1:1) model measurements have been done at the Technical University of Delft in the Netherlands to evaluate the performance of the system SediPipe XL. Research has mainly been done at hydraulic properties and the removal efficiency.

1.2 Project setup of the research of TAUW / TU Delft

TAUW BV and TU Delft together have tested the system SediPipe XL 600/24 in the water lab at TU Delft and have reported on the findings.

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Dr. ir. Frans van de Ven

1.3 Goals of the research of TAUW / TU Delft

- Determine the performance of the storm water treatment system SediPipe XL and XL Plus.

- Verify the results of existing researches. E. g.

IWS 'Institut für Wasserbau und Siedlungswasserwirtschaft' and
IFS 'Ingenieurgesellschaft für Stadthydrologie mbH' as well as
TÜV Rheinland LGA Products GmbH

Figure 1.1: Test reports IWS, IFS and TÜV Rheinland

- Compare the test results of scaled and full scale tests.
- Set up a design guidance for the dimensioning of the SediPipe system to cover the legal requirements for water protection.

1.4 Focus of investigation

The SediPipe system is available in different sizes. The size is for each project individually selected to meet the required treatment performance best suited for the connected area in relation to the design rainfall.

In the test program the SediPipe XL 600/24 and SediPipe 600/24 XL Plus were investigated and the test results were compared to already existing test results.

1.5 Functionality of SediPipe XL Plus

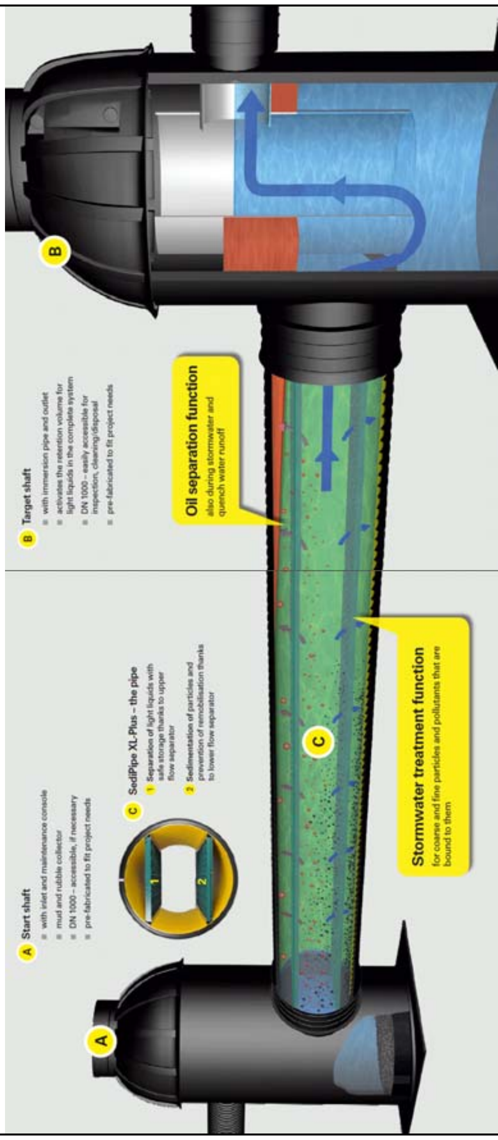


Figure 1.2: SediPipe XL Plus 600/24

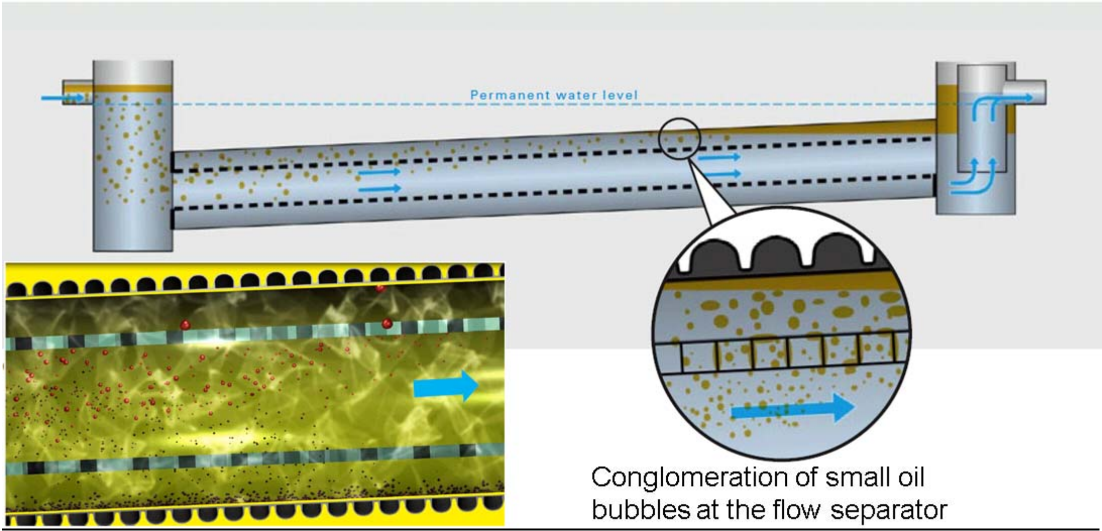


Figure 1.3: Gravity and coalescence principle. Separation of light liquids with SediPipe

1.6 Methodology

1.6.1 The tests

The hydraulic performance and the treatment capacity have been determined both at scaled and at full scale systems SediPipe 600/24. The different tested items / methods of analyses are:

- Flow rate – flow meter
- Removal efficiency - particle counting
- Oil – visual analyses (scaled tests)
- Tracer – visual analyses (scaled tests)

1.6.2 Setup of scaled tests

- SediPipe 600/24
- Scaling factor 1:5
- Plexiglas model
- Operated flow rates up to 5,5 l/s (real flow 300 l/s)
- Test Material: Millisil W4

Figure 1.4: The SediPipe scaled model in the lab of TU Delft

1.6.3 Setup of full scale tests

- SediPipe 600/24
- Pipe DN 600
- Length 24 m
- Manhole DN 1000
- Operated flow rates up to 450 l/s
- Test Material: Millisil W4

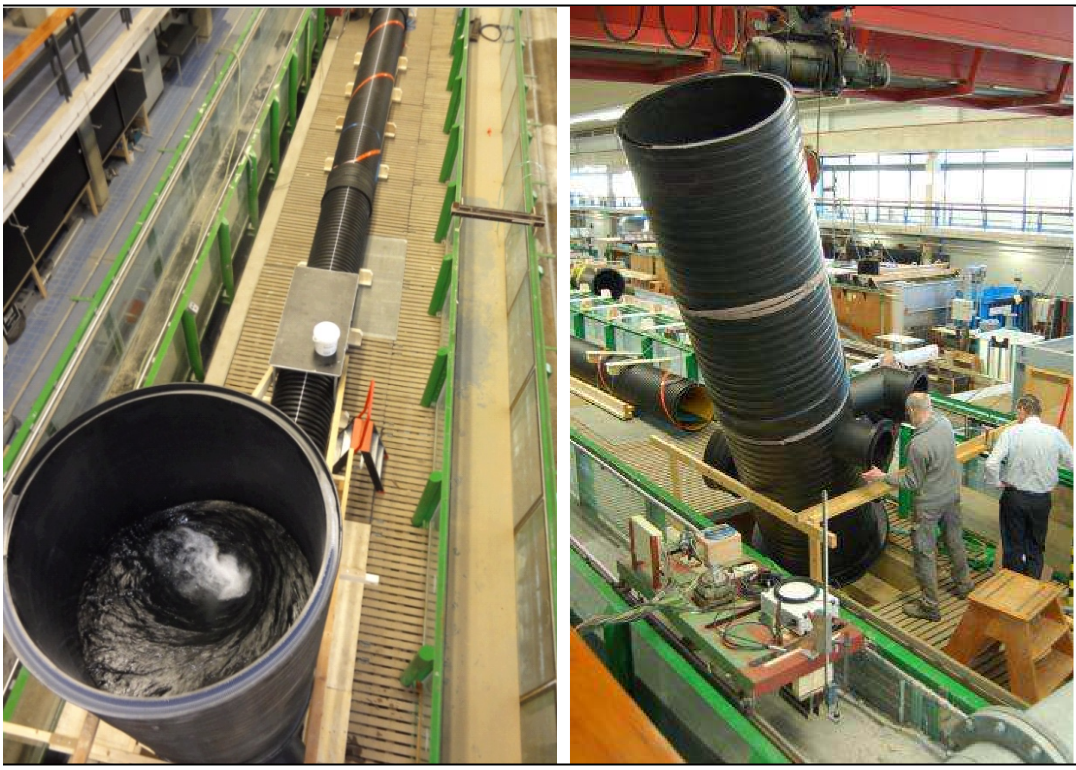


Figure 1.5: The SediPipe in the lab of the TU Delft

1.6.4 Analysis

Table 1.1: Analysis done

	Full scale	Scaled model
Visualization of **flow conditions**, tracer test	x	x
Light liquid		**x**
Removal efficiency (Millisil W4) via particle counting	**x**	**x**
Insight for **hydraulic performance** in flow and water height via data loggers	x	x
Waste tests (plastic bags, bottles, leaves, ...)	**x**	**x**

2 Test results

2.1 Flow conditions – tracer test

For the visualization of the flow conditions of the ‘SediPipe’ and the tracer testing a pigment has been added to the water in the SediPipe model. The chemical used for these tests is potassium permanganate $KMnO_4$).
Potassium permanganate running through the SediPipe:

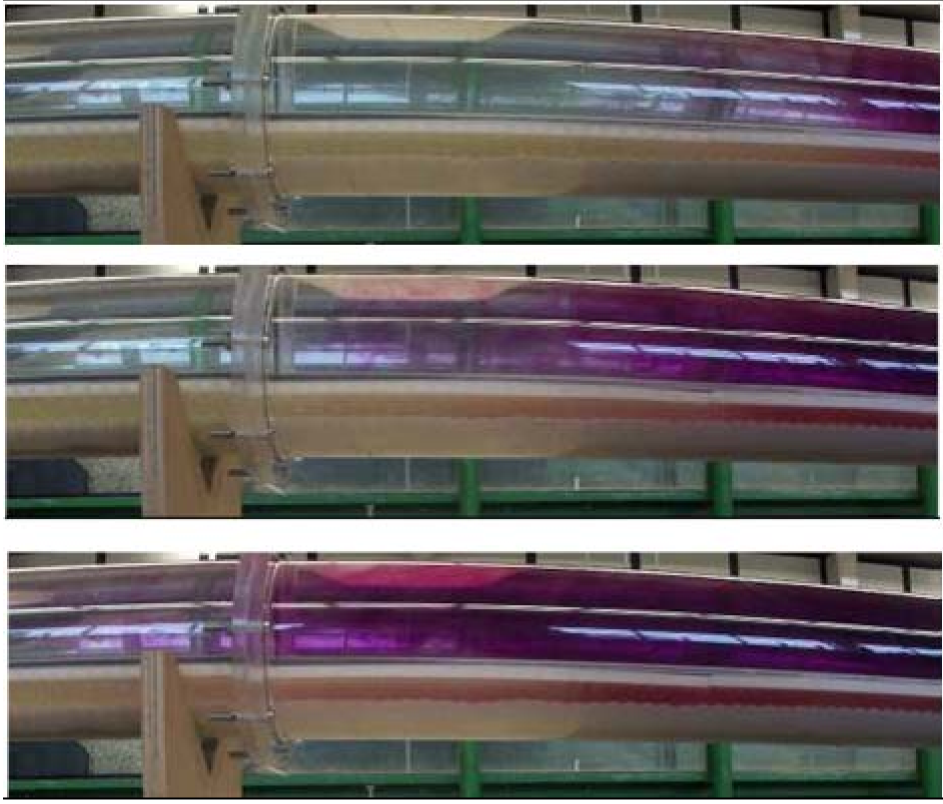


Figure 2.1: $KMnO_4$ in the SediPipe

Conclusions:
- The flow separator is working
- Dominant flow above the flow separator
- This essential feature avoids remobilization of already settled material in the depot

2.2 Light liquids

One add-on functionality – the so called ‘PLUS’ feature - concerns the separation of light-liquids according to DIN EN 858-1 (class I separation)[1]. In case of emergencies (e.g. car accidents) oils in combination with rainfalls or fire fighting run-offs could occur. For these cases the treatment facility should be able to handle the total flow rate and separate the light liquids to a maximum run-off concentration of 5 mg/l which means more than 99% of retention capacity (class I). The carried out tests by a model should give a visualized insight to the separation processes and the capability to keep the separated light liquids in case of following hard storm events.

The separation performance has already been tested successfully and certified on the full scale SediPipe by TÜV Rheinland LGA Products GmbH Sanitär- und Abscheidetechnik in Würzburg, Germany (Prüfbericht Nr. 7310350-01, see chapter 1.3).

For oil separation an additional upper flow separator has been introduced, which should assist to separate the light liquids and direct them via the top level of the SediPipe to a save oil reservoir at the end shaft.

[1] TÜV Rheinland LGA Products GmbH Sanitär- und Abscheidetechnik in Würzburg, Germany (Prüfbericht Nr. 7310350-01, see chapter 1.3).

Conglomeration of oil drops over the length of the SediPipe at the top of the pipe and their movement to the end shaft:

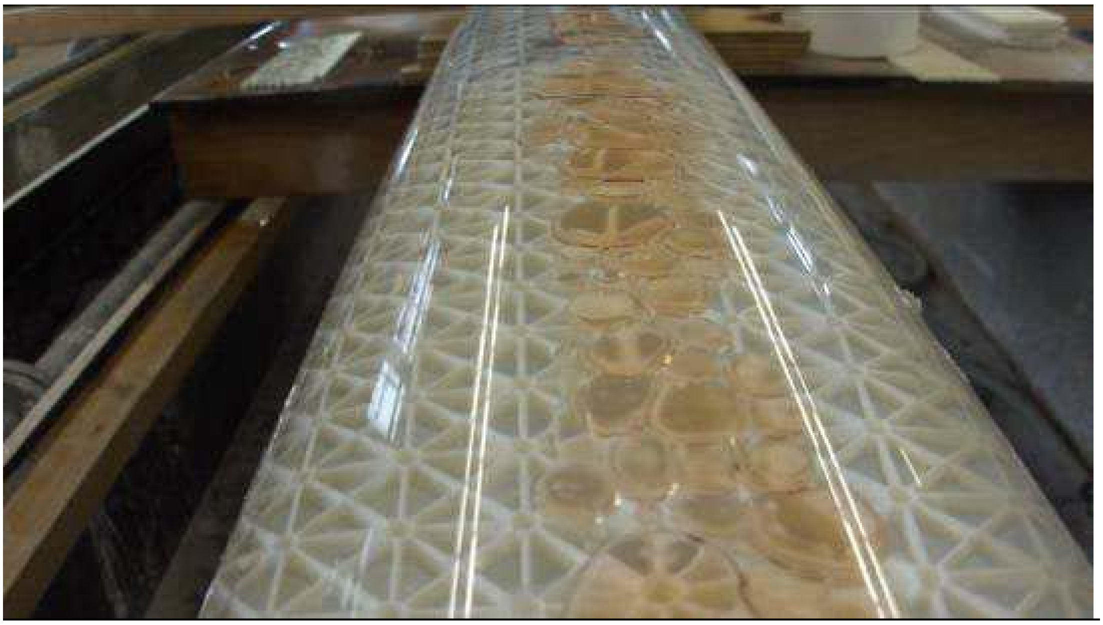


Figure 2.2: Oil caught in the SediPipe

Oil entering the end shaft (depot):

Figure 2.3: Oil entering the depot

The oil is captured by the SediPipe in the end shaft (depot)

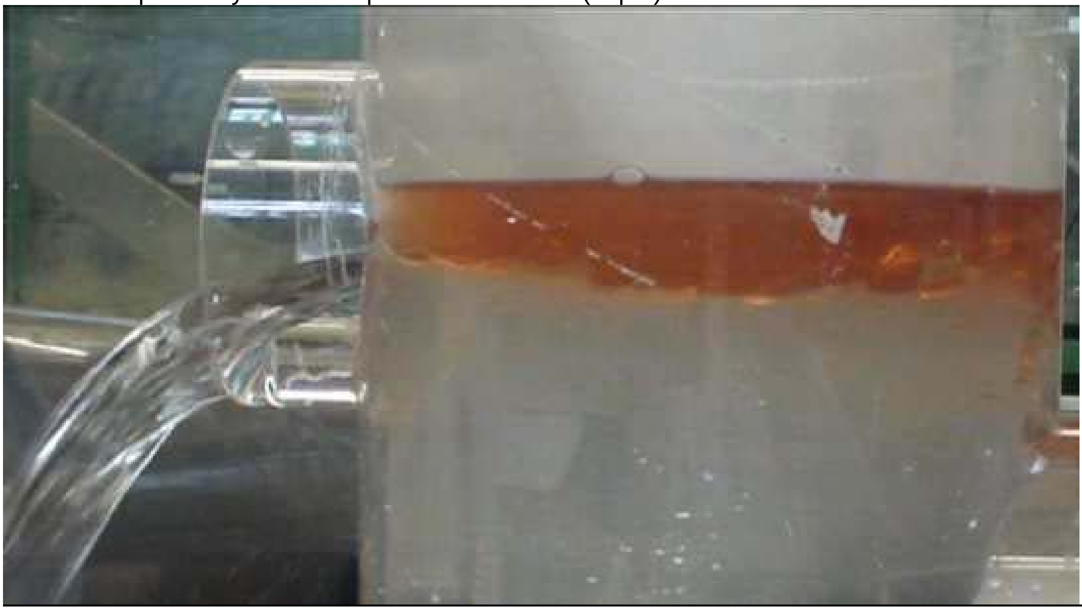


Figure 2.4: Oil in the depot

Oil once being captured in the depot is retained even with high flow rates. The shown flush out test has been operated up to 250 l/s real flow:

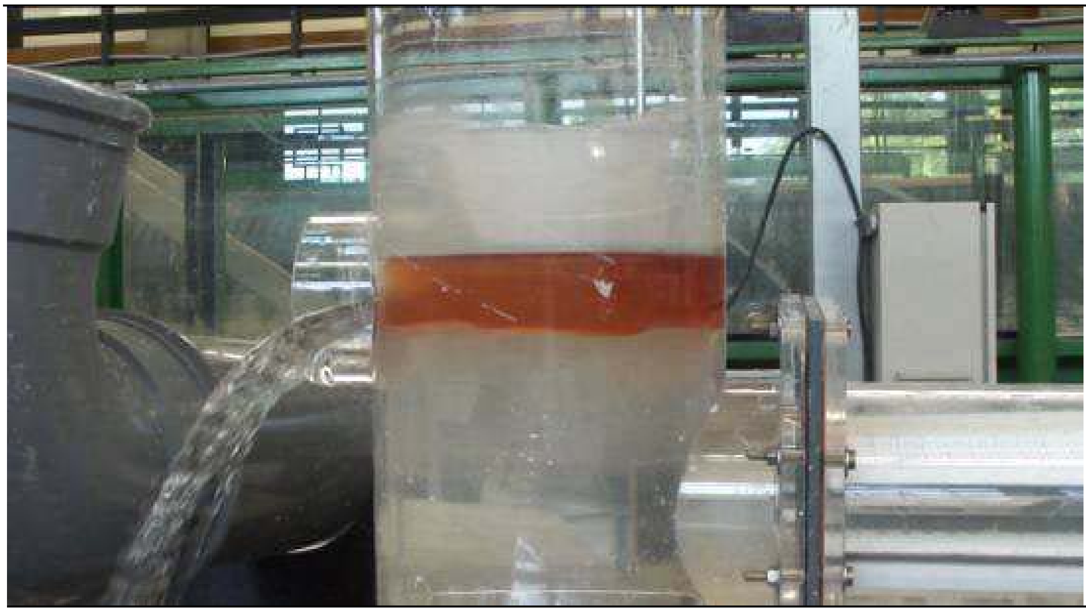


Figure 2.5: No flush out of oil

Conclusions:

- The separation of light liquids also under rainy weather conditions is working
- The light liquids are captured in the end shaft due to the dip pipe
- Even with strong rain events the already captured light liquids are retained safely in the depot
- The extra grid in the upper half of the SediPipe promises added oil removal efficiency class I as tested according DIN EN 858-1 (TÜV Rheinland LGA Products GmbH Sanitär- und Abscheidetechnik: Prüfbericht Nr. 7310350-0).

2.3 Removal efficiency

2.3.1 Micro pollutants in storm water runoff

In water bound pollutants and non-bound pollutants are present. The different types of pollutants adhere in parts to particles, mainly fines of smaller and smallest size. These are the bound parts of the pollutants. The other part of the pollutants remains non-bound.

SediPipe is designed to remove especially the fine particles from the storm water. Thus, bound pollutants can be treated by the SediPipe XL 600/24 via sedimentation of the fine particles.

Note:
Non-bound pollutants in general are not treatable by sedimentation basins. Non-bound pollutants can be removed via other treatment options (like the SediSubstrator).

From the below figure it can be concluded, that for example lead can more easily be treated with an average bounding percentage of 92% (copper 66%, zinc 58%). The average percentage of bound particles for heavy metals in general is 72%. This means that a high removal efficiency rate is needed on suspended solids (and especially small particle sizes) to achieve quality standards.

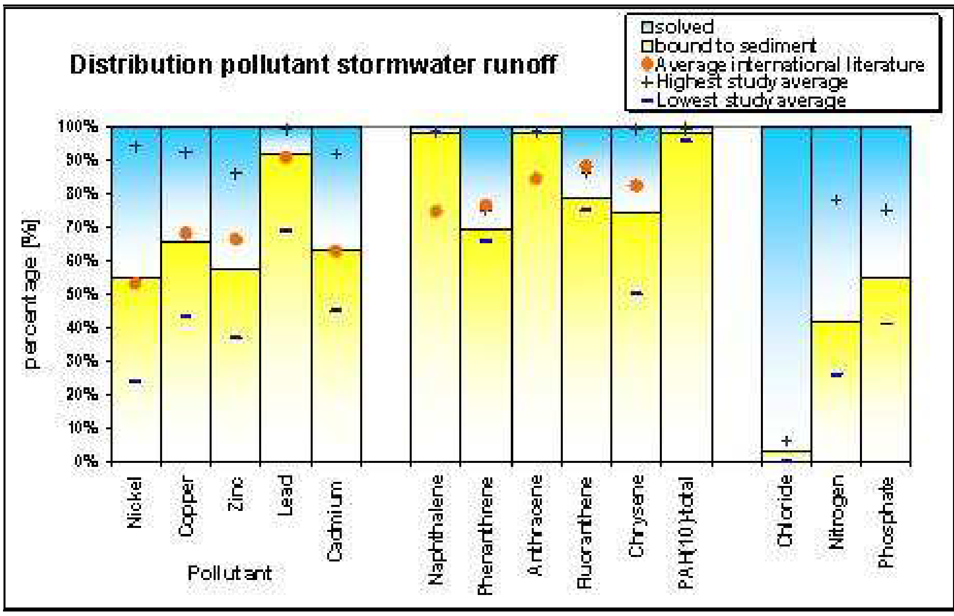


Figure 2.6: Percentage of bound and non-bound pollutants (Boogaard F.C. 2012, SKINT Sustainable Urban Drainage systems research, unpublished.)

Note:
The higher the bounding percentage the more pollutants can be captured throughout sedimentation.

2.3.2 Bound particles versus particle sizes

International research has shown the relation between particle size and binding. It can be seen that relatively most pollutants are bound to the smaller particles (<75 microns).

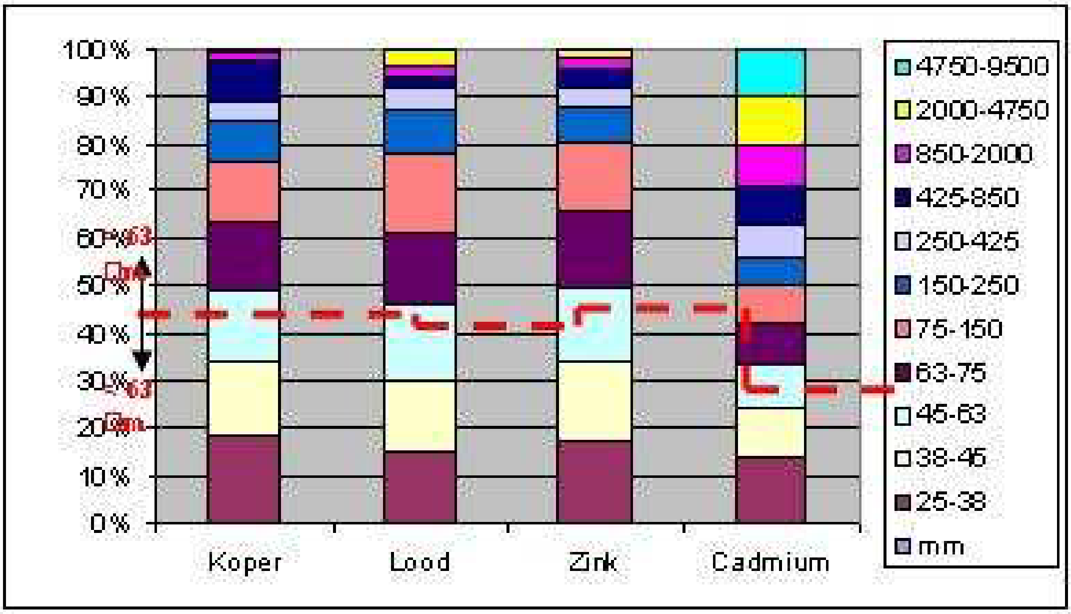


Figure 2.7: Several heavy metals and their bounding factors. (Copper, Lead, Zink and Cadmium) (Boogaard F.C. 2012, SKINT Sustainable Urban Drainage systems research, unpublished.)

2.3.3 Particle sizes in Dutch storm water runoff and the test material

The following graph shows the Dutch particle sizes in stormwater runoff and the test Material Millisil W4 (RED line).

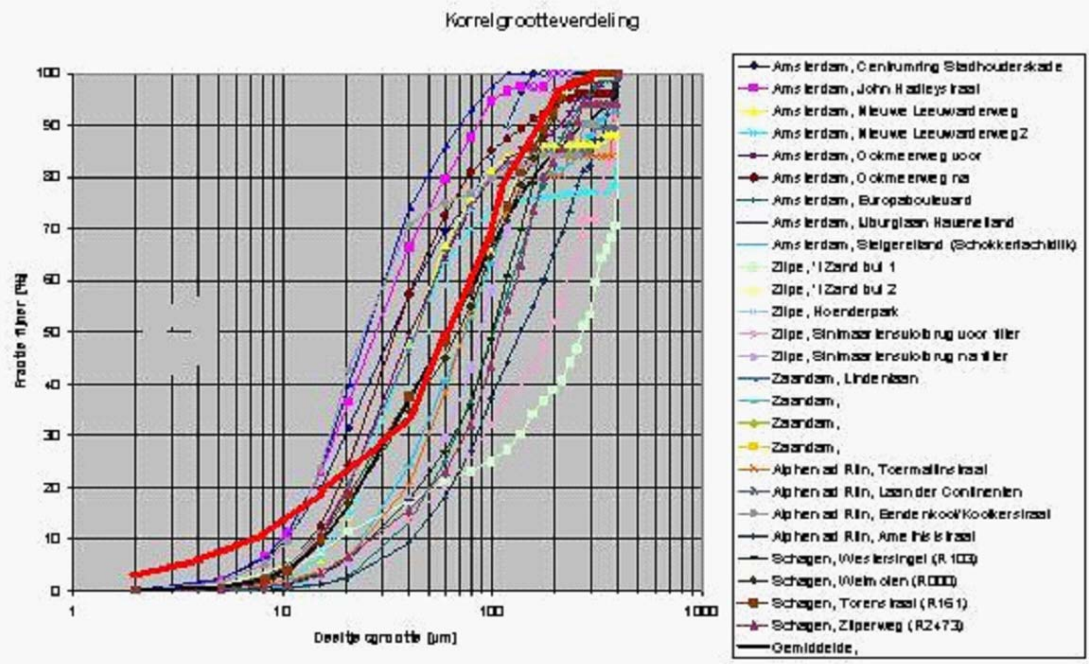


Figure 2.8: Particle sizes in the Netherlands and Millisil W4. Boogaard F.C. 2012, SKINT Sustainable Urban Drainage systems research, unpublished.

Millisil is a quartz material, silicon dioxide (SiO_2), whereat the raw material is processed and refined, subjected to washing, classified, dryed and iron-free grinded. It's typical density is 2,65 g/ml.
Millisil is commonly used as a testing material. It is available in different grain size distributions and it is easily available in the market which guarantees reproducibility of the tests. The Millisil W4 type is fitting the Dutch particle size curve best and is therefore used for this research.

Figure 2.9: Millisil W4

2.3.4 Test results – removal efficiency

The removal efficiency for varying flow conditions has been tested with the scaled and real size systems.

The results can be visualized in the best way looking at the scaled model at different times during one running test.

Beginning of the test: No Sediment in the depot under the flow separator

Figure 2.10: Sedimentation process - beginning

Middle of the test: Depot already half filled with sediment

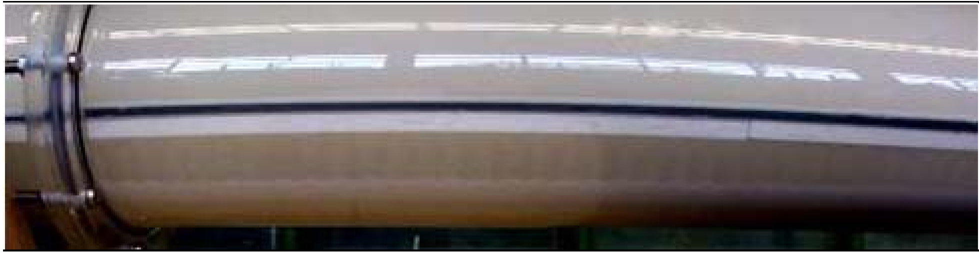


Figure 2.11: Sedimentation process – middle part

Near end of the test: Depot almost filled with sediment

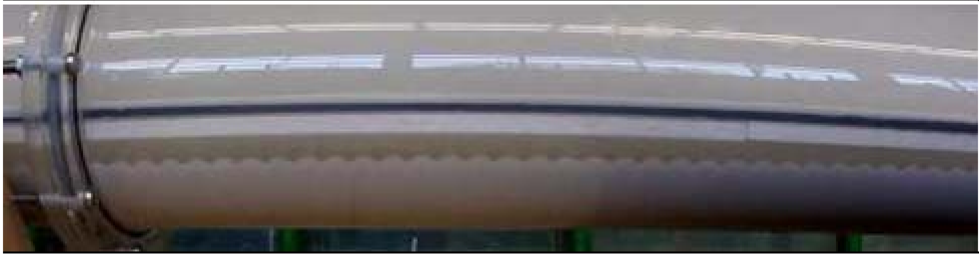


Figure 2.12: Sedimentation process – end part

Test results at TU Delft both for scaled and real sized system:

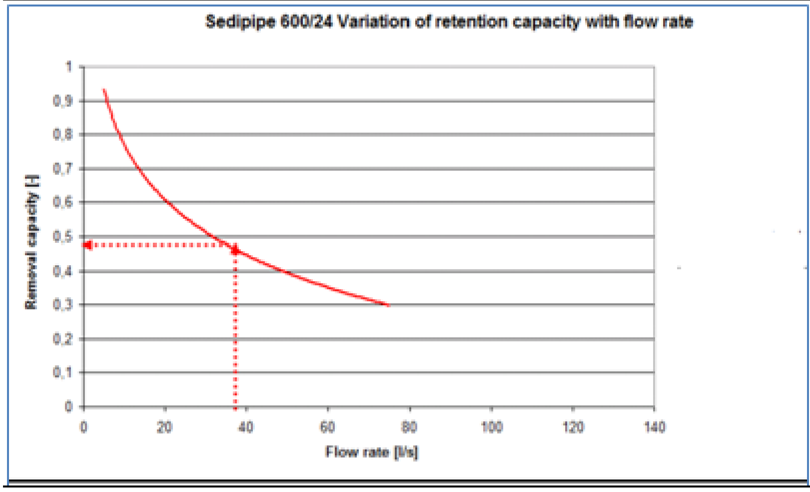


Figure 2.13: Removal efficiency for Millisil W4 of SediPipe XL (with example at 37,5 l/s)

Test results at IWS Leipzig:

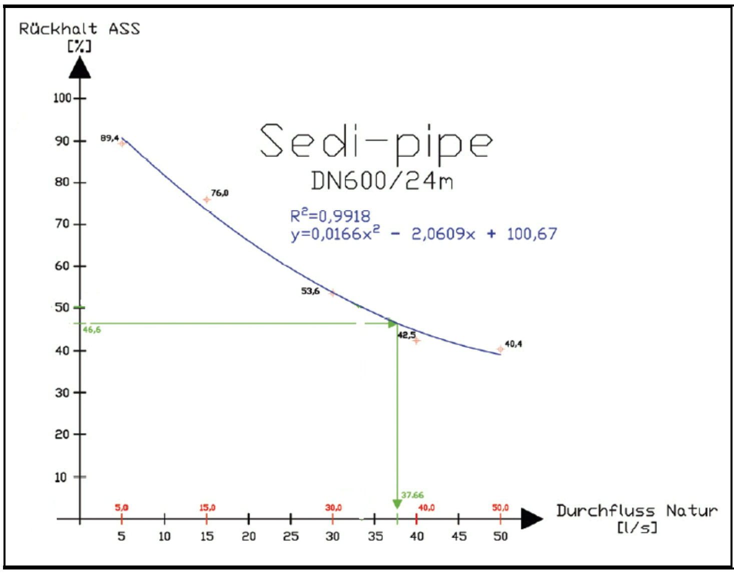


Figure 2.14: Test results of IWS Leipzig

Conclusions:

- The removal rates for the scaled tests are in the same order as the rates of the full size tests
- The removal rates found at the TU Delft are in the same order as the research results gained in other laboratory studies in Europe
- The treatment performance of the former tests e. g. at HTWK in Leipzig is validated

2.3.5 Test results – Waste tests

Why tests for “waste”?

In order to prove the functionality of the system also under conditions where litter is entering to the device a special test setup was created. This test finally is of high importance as the system must work perfectly well also under those conditions. The system must show that no special maintenance effort is required e. g. due to clogging.

The following forms of “large” waste have been documented:

- Plastic sandwich bags
- Plastic chips bags
- Tin drinking can (6 pieces of 0,33 litre and opened)
- Pet bottle (4 pieces of 0,5 litre and opened)
- Leaves (around 100 pieces)

Figure 2.15: Storm water sewer (Amsterdam 2012)

Result:

- SediPipe removes all of the none natural waste and removes most of the natural waste.
- These kinds of waste will not negatively influence the functionality of SediPipe and could easily be taken out of the system by standard maintenance process (high pressure cleaning)

3 Design guidelines

3.1 Basics

Approach:

- Performance „Removal Capacity versus Flow Rate“ is known from the tests
- The grain sizes captured are known from the tests
- It is known how many of the heavy metals are bound to fine materials that can be sedimented
- The annually treatable rain events are known (see next paragraph)

3.2 Basic data – Total annual rainwater in SediPipe versus flow

The following graph shows the ratio of the annually falling rainwater in [%], which is discharged through the SediPipe vs the norm discharge rate in [l/sha].

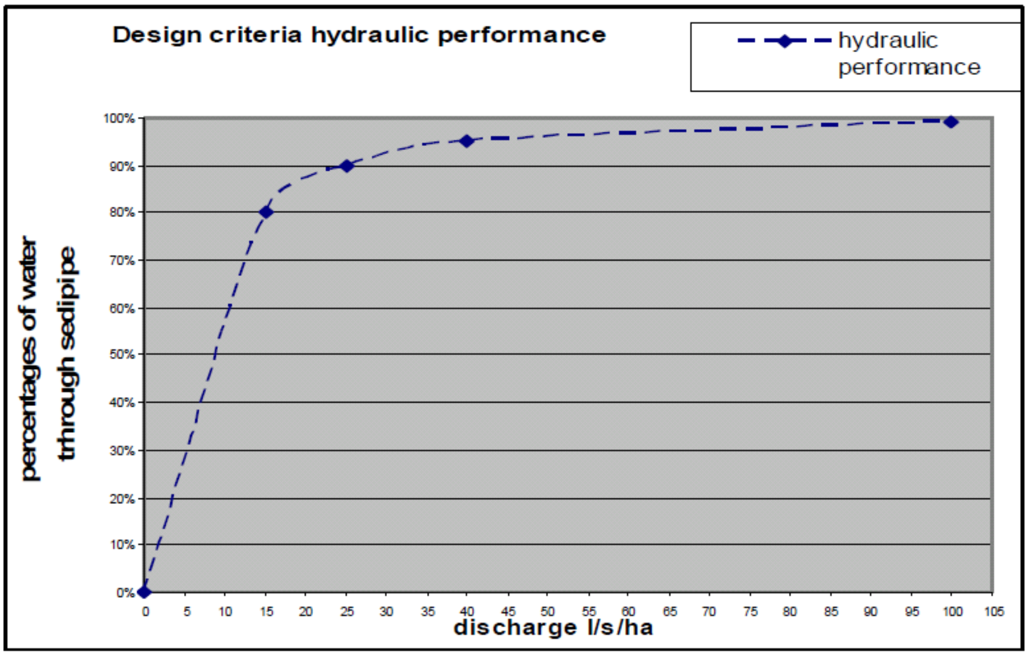


Figure 3.1: Statistical occurance of flow rates per hectare in the Netherlands (Boogaard F.C. 2012, SKINT Sustainable Urban Drainage systems research, unpublished.)

The graph is the result of a model calculation on the occurrence of discharge from connected areas with a 25 year rainfall dataset when applying the most regular Dutch model requirements.

As can be seen in the graph, when applying for example a 14 l/sha design rainfall, about 80% of the average annual storm water is covered by that and will therefore be treated when running through the SediPipe. In the following chapters this percentage will be called the ‘hydraulic occurrence’. The related norm discharge flow rate in l/sha is given to complete the data for the design of the SediPipe.

3.3 Guidelines for implementation

3.3.1 Design graph theory

All those data finally lead to a design graph which shows:

- Considering all rain events throughout a year (small rains with high sedimentation performance and stronger rain events with lower sedimentation performance) the annually captured fine particles in %
- The connectable paved surface area in m²
- The requested norm discharge flow rate in l/sha to be treated
- The occurrence of average annual rainfalls in % covered by the norm discharge flow rate

Note:
With an additional table the captured amount of retained heavy metals in % can be determined. Sand and larger grain sizes are retained by 100%.

3.3.2 Design graph

As an example here the design graph for the SediPipe 600/24. The complete range of design graphs are presented in the Annex.

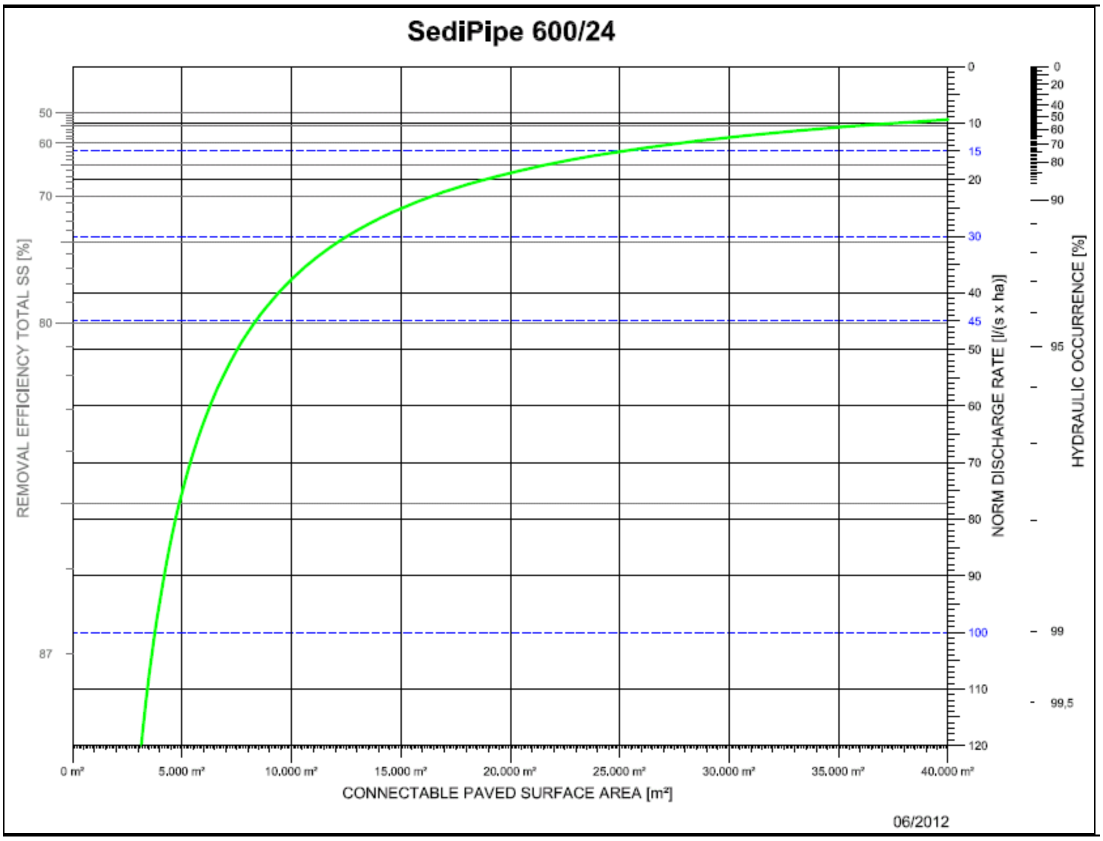


Figure 3.2: Design graph SediPipe 600/24

Table 3.1: Design table (complementary to the design graph)

Connected Area [ha]	Total SS [%]	Total Copper [%]	Total Lead [%]	Total Zinc [%]
0	100	66 (100%)*	92 (100%)*	54 (100%)*
0.5	85	56 (85%)*	78 (85%)*	46 (85%)*
1	78	51 (78%)*	71 (78%)*	42 (78%)*
2	66	44 (66%)*	61 (66%)*	36 (66%)*
3	58	39 (58%)*	54 (58%)*	32 (58%)*

()* Total removed amount of heavy metal bound to suspended solids

Note: The flow separator avoids remobilization of already settled material for rainfall events that have to be treated. The depot for settled fine particles is safe. However, for extreme rainfall events a by-pass is recommended especially for avoiding submerging water levels in the network.

3.3.3 Example

1 ha paved area shall be connected and treated.

Step 1:

Enter the graph with the paved area and find

- The total annually captured sediment with connected area of 1 ha is in the order of 78 %.
- The information that the norm discharge flow rate of 37 l/sha is treated. Multiplied with the connected area it is an actual flow of 37 l/s. This finally covers approx. 93 % of the annual rainfall events.

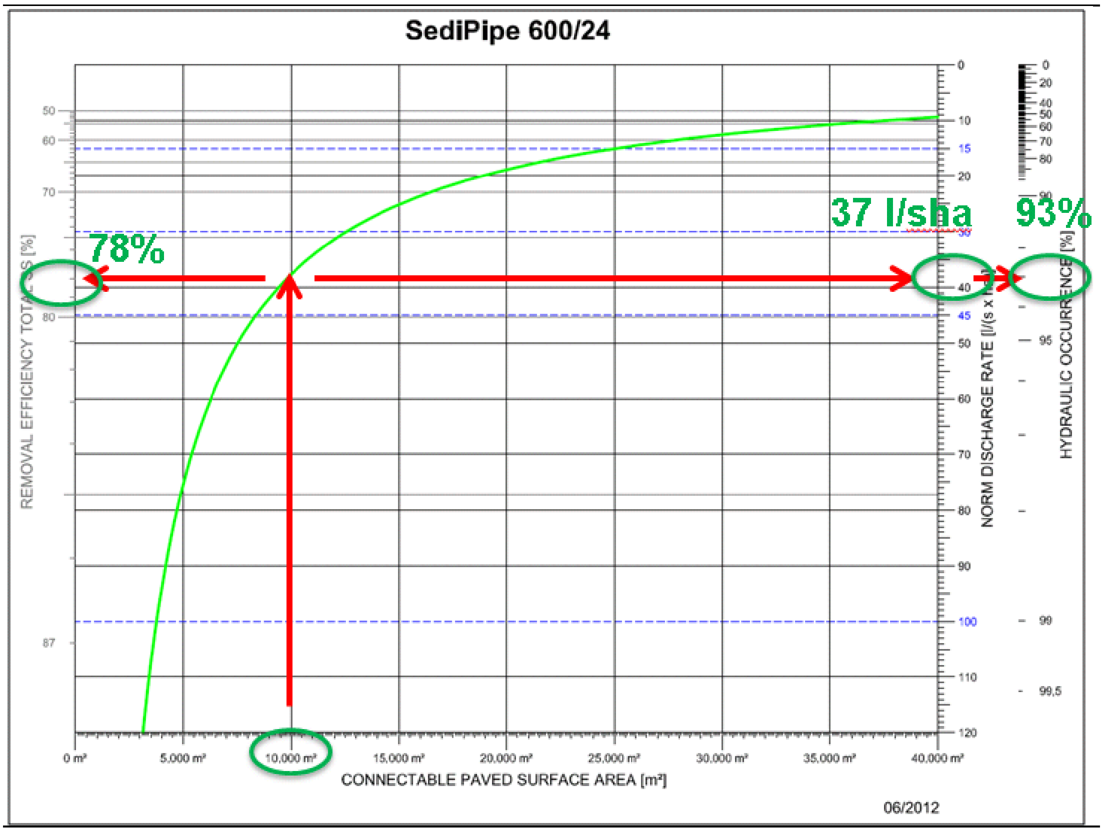


Figure 3.3: Example for dimensioning a SediPipe 600/24

Step 2:
The table shows depending on the connected catchment area the total amount of annually captured suspended solids, copper, lead and zinc. In brackets, the numbers for the heavy metals show the respective amount in relation to the bound part. This is the part which is treatable at all via sedimentation.

Table 3.1: Design table (complementary to the design graph)

Connected Area [ha]	Total SS [%]	Total Copper [%]	Total Lead [%]	Total Zinc [%]
0	100	66 (100%)*	92 (100%)*	54 (100%)*
0.5	85	56 (85%)*	78 (85%)*	46 (85%)*
1	78	51 (78%)*	71 (78%)*	42 (78%)*
2	66	44 (66%)*	61 (66%)*	36 (66%)*
3	58	39 (58%)*	54 (58%)*	32 (58%)*

()* Total removed amount of heavy metal bound to suspended solids

Figure 3.4: Example for dimensioning a SediPipe 600/24

In this example, for 1 ha catchment area there is 78 % of suspended solids annually captured. 51% of copper, 71 % of lead and 42 % of Zinc are captured with the sediment.

4 Conclusions

After intensive testing in the laboratory and a translation of these results to practice the following conclusions can be made on the performance of SediPipe:

Flow separation:

- The flow separator avoids remobilization of already settled material for rainfall events within its advised application range. For extreme rainfall events a by-pass is recommended especially to avoid submerging water levels in the storm water system.

Light liquids:

- The separation of light liquids also under rainy weather conditions is working.
- Even with strong rain events the already captured light liquids are retained safely in the depot.
- The extra grid in the upper half of the SediPipe promises added oil removal efficiency class I as tested according DIN EN 858-1[2].

Removal efficiency of fine particles and pollutants:

- The concept of reducing emission by removal of small particles with adherent pollutants is working.
- The removal rates for the scaled tests are in the same order as the rates of the full size tests.
- The removal rates found at the TU Delft are consistent with the research results gained in other laboratory studies in Europe.
- The treatment performance of the former tests e. g. at HTWK in Leipzig is validated.
- Within its advised application range the SediPipe XL 600/24 can treat between 70% up to 99% of all rainfall occurrences.
- SediPipe removes high quantities of the none course natural waste and removes most of the natural waste without a negative effect on the functionality of SediPipe. Waste can easily be taken out of the system by standard maintenance process (high pressure jetting).

Finally:

The SediPipe system is removing micro-pollutants (e.g. PAHs and heavy metals), light liquids, fine particles (< 0,06 mm) and sand (> 0,06 mm) from the storm water runoff.

It reduces the negative effect on the environment from the pollutants and can improve the functionality of Sustainable Urban Drainage Systems (SUDS) from e. g. clogging due to fine

[2] TÜV Rheinland LGA Products GmbH Sanitär- und Abscheidetechnik in Würzburg, Germany (Prüfbericht Nr. 7310350-01, see chapter 1.3).

particles. It reduces the maintenance efforts and guarantees the investment's rentability and durability.

With this research, a design guidance for the dimensioning of the SediPipe system to cover these requirements was set up.

Since most of the research results are gained in laboratory circumstances it's advisable to monitor the SediPipe in the field to gain more information on its performance and required maintenance.

Appendix

1

Overview design graphs SediPipe

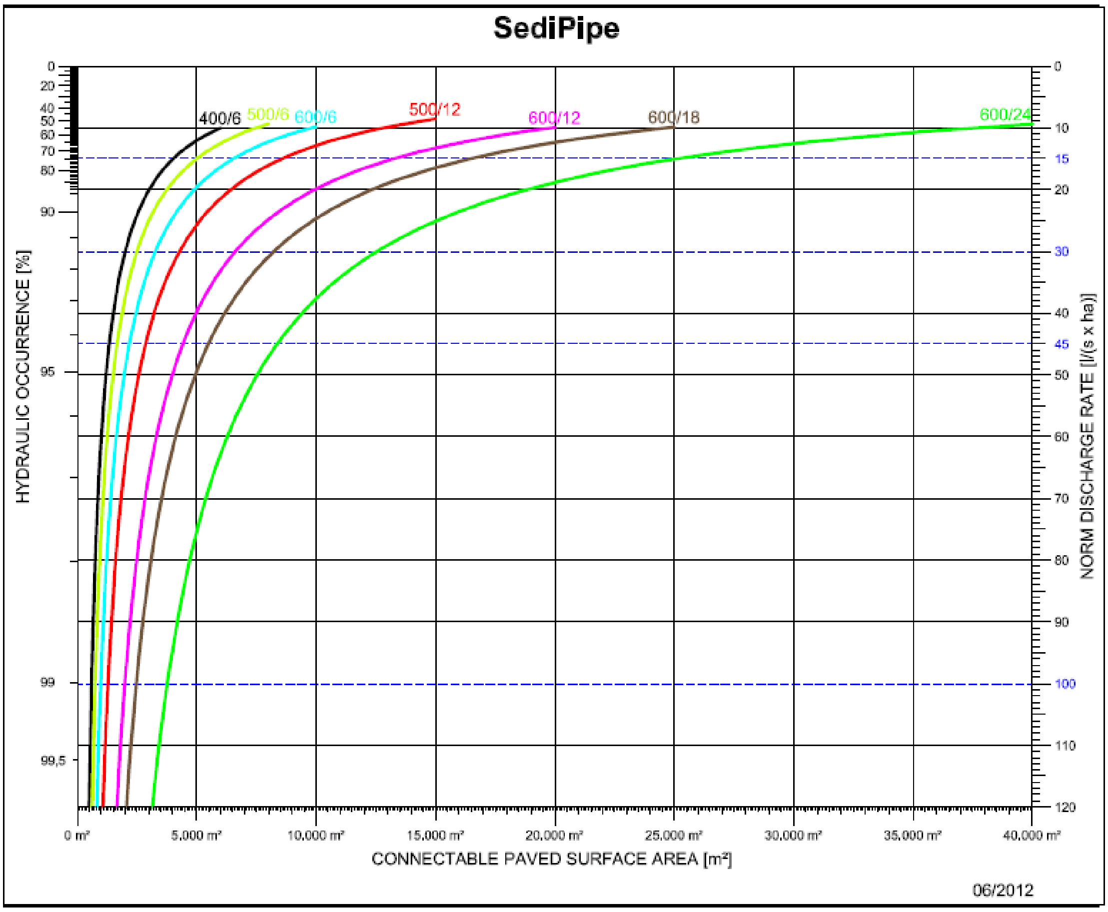
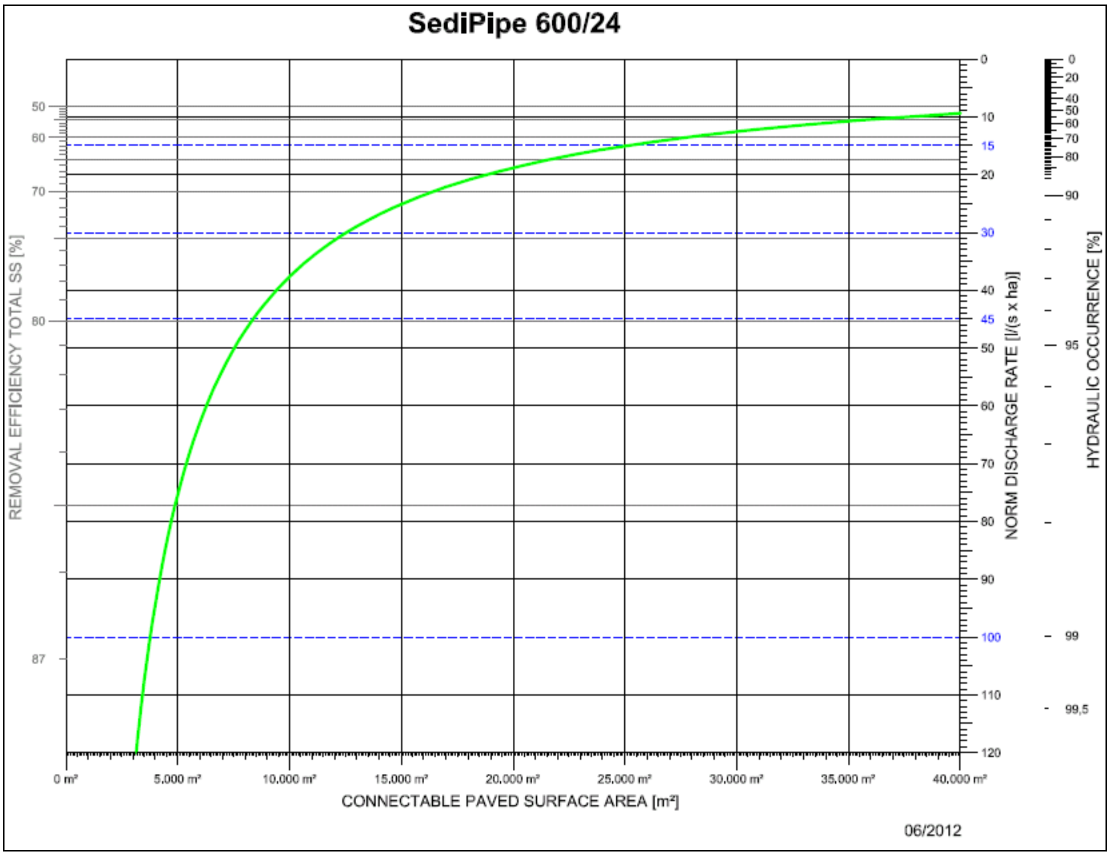


Figure 4.1: Overview design graphs SediPipe

Appendix

2

Design graphs SediPipes

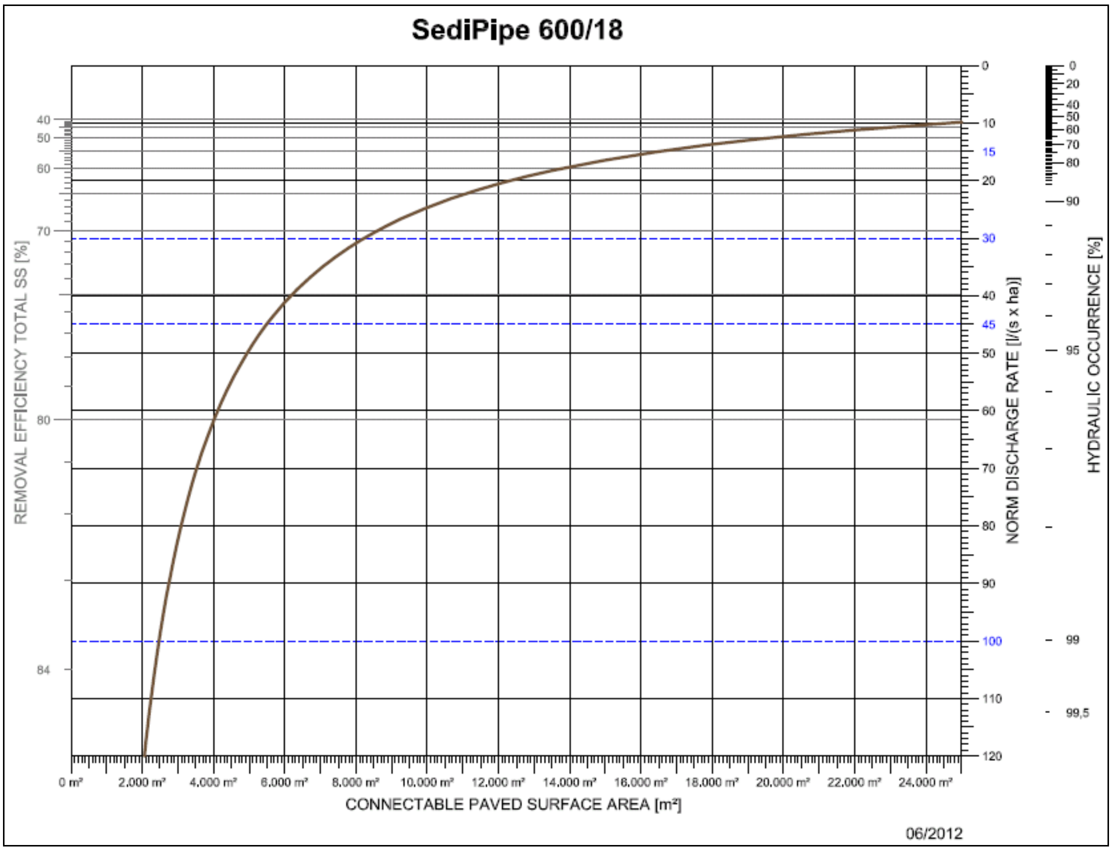


Design graph SediPipe 600/24

Connected paved Area [ha]	Total SS [%]	Total Copper [%]		Total Lead [%]		Total Zinc [%]	
0	100	66	(100%)*	92	(100%)*	54	(100%)*
0,5	85	56	(85%)*	78	(85%)*	46	(85%)*
1	78	51	(78%)*	71	(78%)*	42	(78%)*
2	66	44	(66%)*	61	(66%)*	36	(66%)*
3	58	39	(58%)*	54	(58%)*	32	(58%)*

()* Total removed amount of heavy metal bound to suspended solids

Captured heavy metals and the connected paved area for SediPipe 600/24

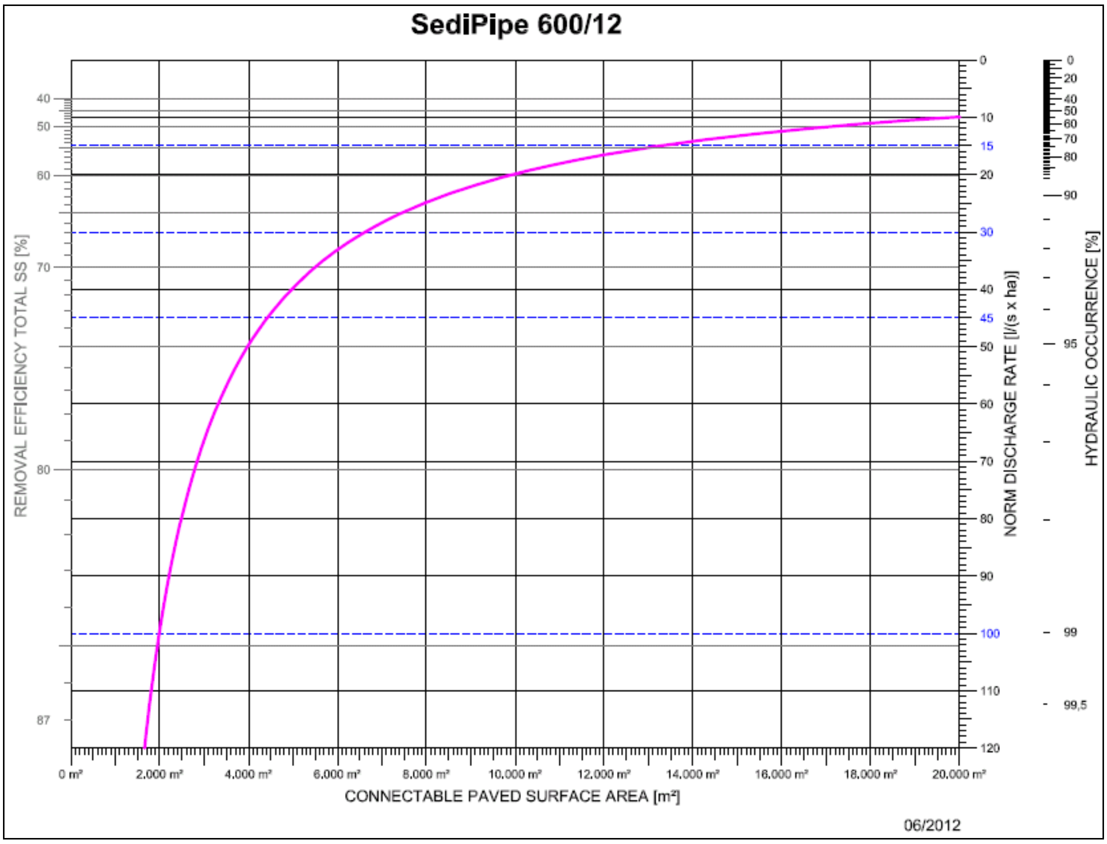


Design graph SediPipe 600/18

Connected paved Area [ha]	Total SS [%]	Total Copper [%]		Total Lead [%]		Total Zinc [%]	
0	100	66	(100%)*	92	(100%)*	54	(100%)*
0,2	85	56	(85%)*	78	(85%)*	46	(85%)*
0,3	83	55	(83%)*	76	(83%)*	45	(83%)*
1	67	44	(67%)*	62	(67%)*	36	(67%)*
3	34	23	(34%)*	32	(34%)*	19	(34%)*

()* Total removed amount of heavy metal bound to suspended solids

Captured heavy metals and the connected paved area for SediPipe 600/18

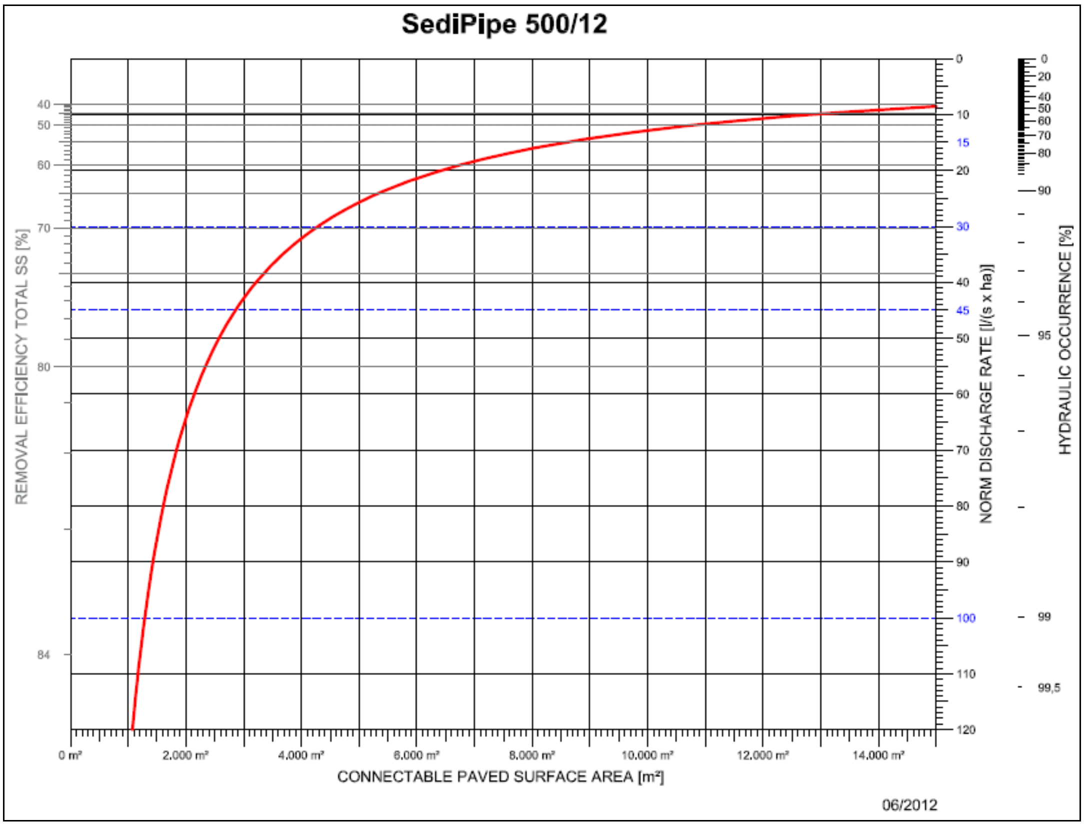


Design graph SediPipe 600/12

Connected paved Area [ha]	Total SS [%]	Total Copper [%]		Total Lead [%]		Total Zinc [%]	
0	100	66	(100%)*	92	(100%)*	54	(100%)*
0,2	85	56	(85%)*	78	(85%)*	46	(85%)*
0,5	72	47	(72%)*	66	(72%)*	39	(72%)*
0,8	64	42	(64%)*	59	(64%)*	34	(64%)*
1	60	39	(60%)*	55	(60%)*	32	(60%)*

()* Total removed amount of heavy metal bound to suspended solids

Captured heavy metals and the connected paved area for SediPipe 600/12

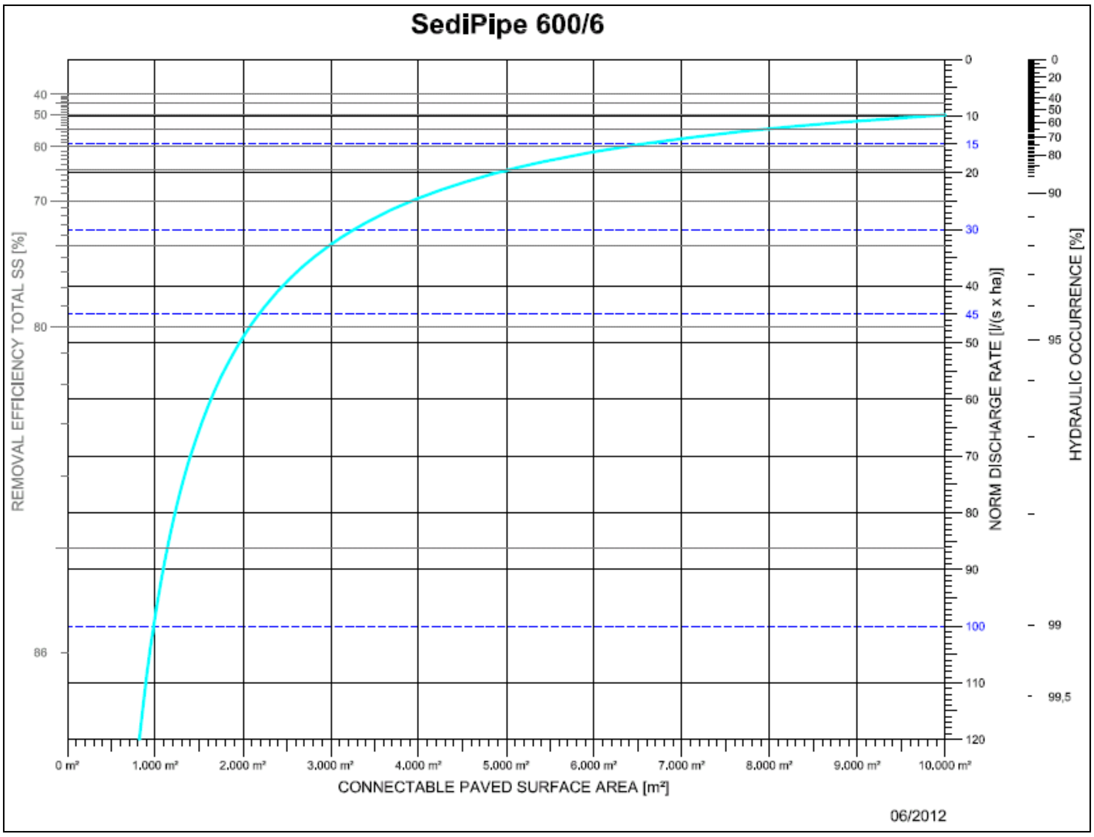


Design graph SediPipe 500/12

Connected paved Area [ha]	Total SS [%]	Total Copper [%]	Total Lead [%]	Total Zinc [%]
0	100	66 (100%)*	92 (100%)*	54 (100%)*
0,1	85	56 (85%)*	78 (85%)*	46 (85%)*
0,2	81	54 (81%)*	75 (81%)*	44 (81%)*
0,5	66	44 (66%)*	61 (66%)*	36 (66%)*
0,8	57	37 (57%)*	52 (57%)*	31 (57%)*

()* Total removed amount of heavy metal bound to suspended solids

Captured heavy metals and the connected paved area for SediPipe 500/12

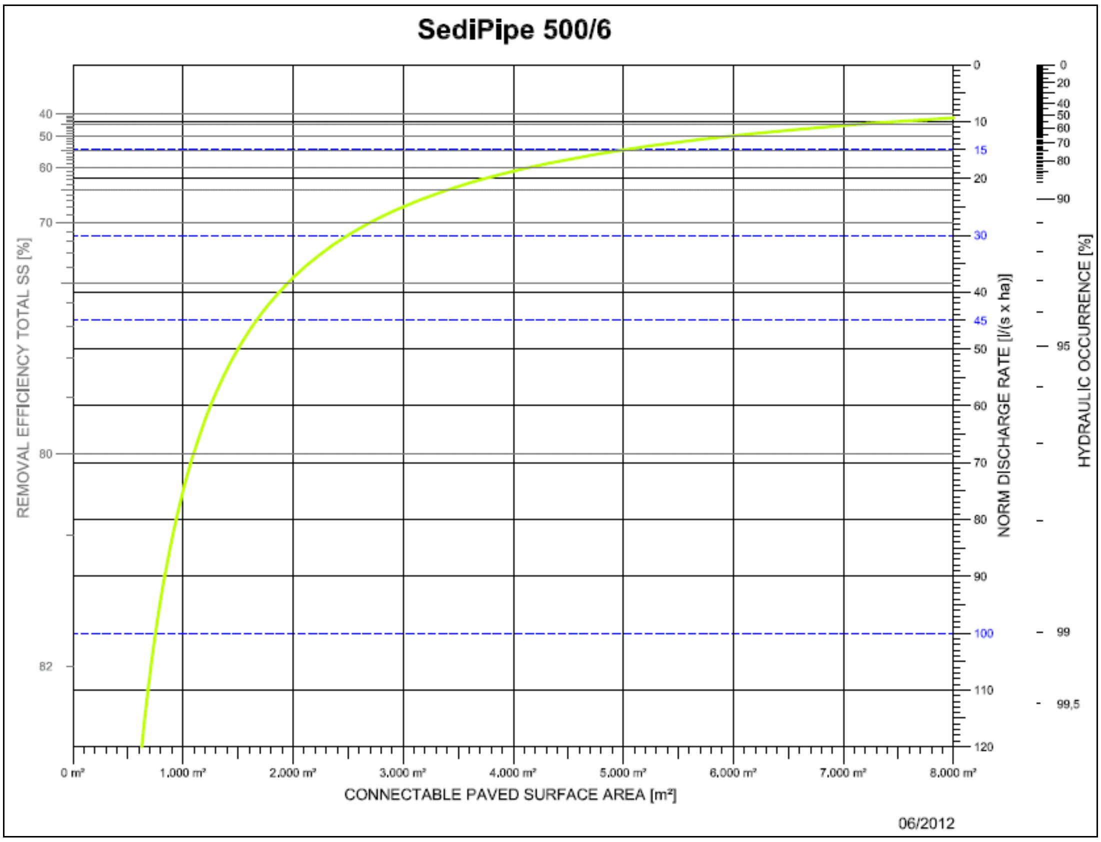


Design graph SediPipe 600/6

Connected paved Area [ha]	Total SS [%]	Total Copper [%]		Total Lead [%]		Total Zinc [%]	
0	100	66	(100%)*	92	(100%)*	54	(100%)*
0,1	86	57	(86%)*	79	(86%)*	46	(86%)*
0,3	75	49	(75%)*	69	(75%)*	40	(75%)*
0,5	65	43	(65%)*	60	(65%)*	35	(65%)*

()* Total removed amount of heavy metal bound to suspended solids

Captured heavy metals and the connected paved area for SediPipe 600/6

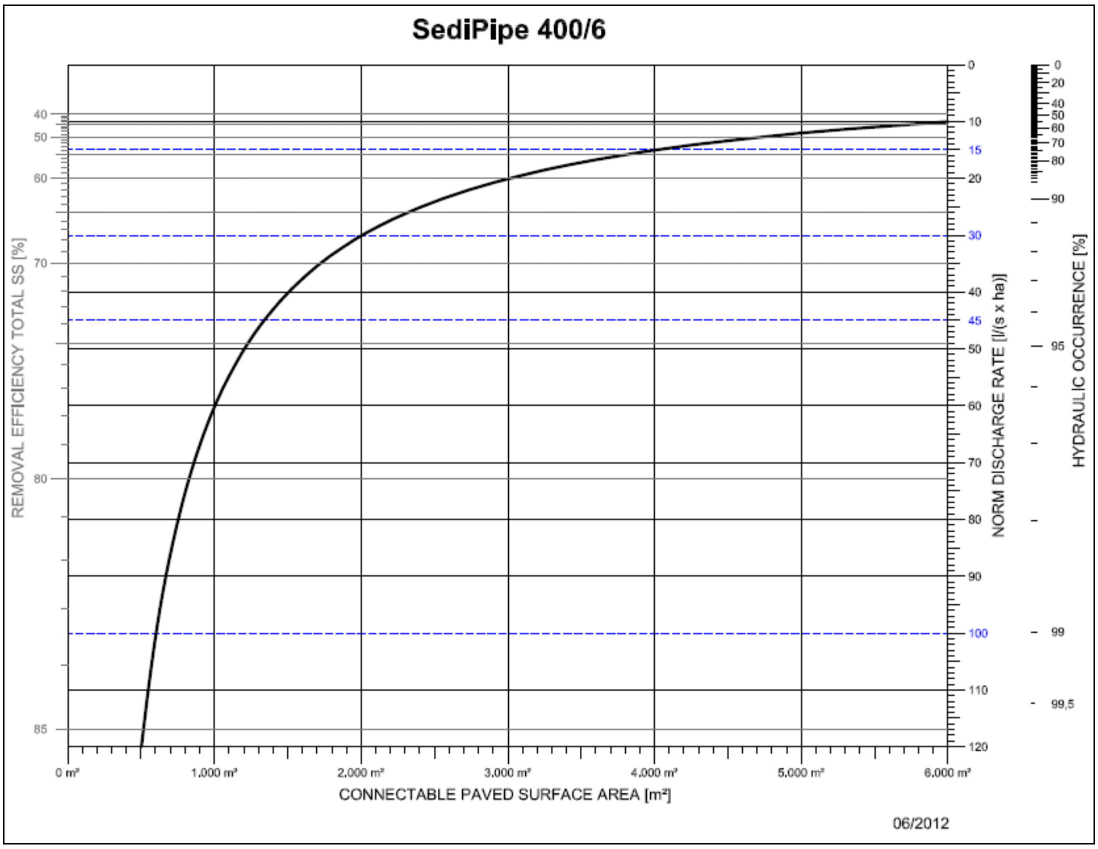


Design graph SediPipe 500/6

Connected paved Area [ha]	Total SS [%]	Total Copper [%]		Total Lead [%]		Total Zinc [%]	
0	100	66	(100%)*	92	(100%)*	54	(100%)*
0,1	81	53	(81%)*	74	(81%)*	43	(81%)*
0,2	75	49	(75%)*	69	(75%)*	40	(75%)*
0,3	68	45	(68%)*	62	(68%)*	37	(68%)*

()* Total removed amount of heavy metal bound to suspended solids

Captured heavy metals and the connected paved area for SediPipe 500/6



Design graph SediPipe 400/6

Connected paved Area [ha]	Total SS [%]	Total Copper [%]		Total Lead [%]		Total Zinc [%]	
0	100	66	(100%)*	92	(100%)*	54	(100%)*
0,1	78	51	(78%)*	71	(78%)*	42	(78%)*
0,2	68	45	(68%)*	62	(68%)*	36	(68%)*
0,3	60	40	(60%)*	55	(60%)*	32	(60%)*

()* Total removed amount of heavy metal bound to suspended solids

Captured heavy metals and the connected paved area for SediPipe 400/6