Evaluation and feedback of rainwater treatment efficiency based on fines particles and associated pollutants by decantion

Retour d'expérience et évaluation de la performance d'un système de traitement des eaux pluviales par décantion des matières en suspensions et des polluants associés

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RÉSUMÉ

Les eaux pluviales contiennent des micros polluants (HAP / métaux lourds). Ces polluants peuvent avoir un impact sur la qualité des sols, de la nappe phréatique et des eaux de surface.
Des systèmes de traitement innovants, économiques et performants sont requis pour répondre à ces nouveaux enjeux. Ces systèmes ont un intérêt supplémentaire dans la fonction de protection des techniques alternatives par une protection du risque de colmatage par les sables et particules fines.
Ces systèmes permettent de réduire la maintenance des ouvrages et de garantir les performances et la durabilité de l'investissement dans les systèmes d'infiltration et autres techniques alternatives.
L'un de ces systèmes de traitement est le Sedipipe de Fraenkische déjà utilisé dans plusieurs cas aux Pays Bas. Différentes expérimentations sur les performances hydraulique et les capacités de traitement du Sedipipe par différentes organisations en Allemagne. Des essais sur modèles réduits en 2010/2011 à l'échelle 1:5 et à l'echelle 1:1 ont été réalisés à l'université technique de Delft aux Pays Bas pour évaluer les performances du système sedipipe XL. L'étude à été menée sur les propriétés hydraulique et sur les capacités de traitement.

ABSTRACT

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 such as SediPipe from FRÄNKISCHE are required to mitigate these effects. They are easy to implement and maintain which is a crucial attribute of the system especially for its application in dense urban areas. The SediPipe system is for a long time implemented in Europe and well proven in use. Various studies of well-respected laboratories approved the performance of the system already. The studies comprise the treatment performance as well as the hydraulic properties.
The latest research was carried out in the years of 2011 and 2012 in the Netherlands at the water lab of the TU Delft. There were in the first part of the research carried out scaled and full scale tests to end up with a comparison and check for the reliability of the scaled tests. The second part of the research develops a path breaking method for the design of storm water treatment systems for the Netherlands.

KEYWORDS

Cost effective, Design method, Micro pollutants, Storm water, Treatment system, Water quality

1 INTRODUCTION

1.1 Introduction

Storm water treatment systems are of special interest for the investor as they not only mitigate negative effects on the soil and groundwater but in addition 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.

The SediPipe system for storm water treatment from Fränkische is successfully implemented in the markets of Europe already since years. Numerous experiments have been done up to now to evaluate the hydraulic performance and treatment capacity of the SediPipe system by several organizations in Germany.

In the years of 2010 and 2011 scaled (1:5) and full size (1:1) measurements have been done at the Technical University of Delft in the Netherlands to evaluate the performance of the system and to set up a recommendation for the design of the SediPipe as a storm water treatment device in the Netherlands.

1.2 Project setup of the research

TAUW BV, a leading consultant agency in the Netherlands, was part of the project team. Project leader was Ir. F.C. (Floris) Boogaard (TAUW/TU Delft), Zekeringstraat 43g, Postbus 20748, 1001 NS Amsterdam. Professor / Head of Laboratory was Sander de Vree. Professor/Technical consultant / Phd counselor was 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.
- 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
- Compare the test results of scaled and full scale tests.
- Set up a design guidance for the dimensioning of the SediPipe system in the Netherlands to cover the legal requirements for water protection.

1.4 Functionality of SediPipe XL Plus

The treatment functionality to be tested and analyzed bases on two principles:

- The suspended solids sink down and are caught by the lower flow separator. They are kept safely in the depot which is located below the flow separator. The flow separator guarantees the protection of the depot for the suspended solids also during heavy rain events with high flow rates.
- The light liquids in case of accident move upwards and are caught by the upper flow separator. The dip pipe in the target shaft keeps the light liquids in the system. The depot is safe also with high flow.

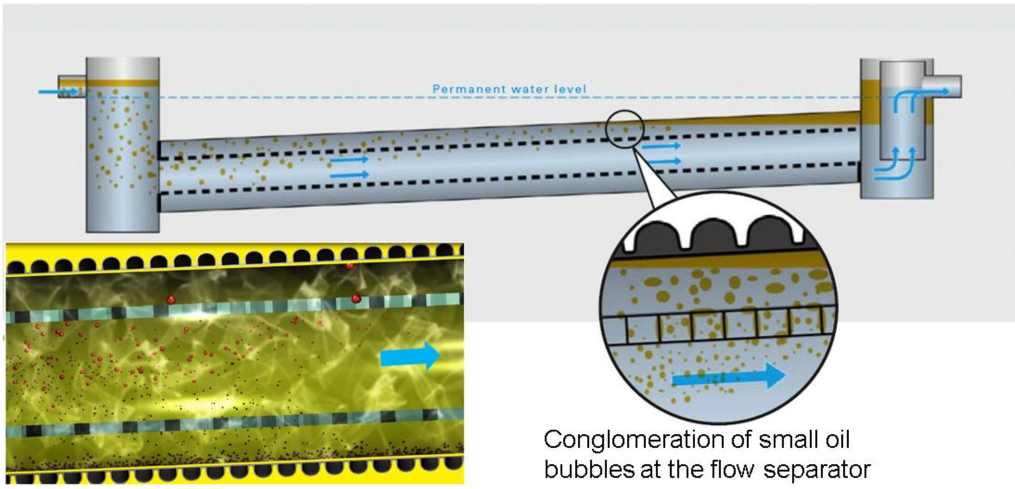

Figure 1: Working principle of SediPipe XL. Separation of light liquids and sedimentation of suspended solids [1]

1.5 Methodology

1.5.1 The tests

The hydraulic performance and the treatment capacity have been determined both at scaled and at full scale systems.

Table 1: Analysis done [1]

	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

1.5.2 Setup of scaled tests

A plexiglas model of the SediPipe 600/24 with the scaling factor of 1:5 was operated with flow rates up to 5,5 l/s (real flow 300 l/s).The test Material was Millisil W4.

1.5.3 Setup of full scale tests

The SediPipe 600/24 was with a pipe DN 600 and a length of 24 m and manholes DN 1000 was in full scale operated with flow rates up to 450 l/s. The test Material was Millisil W4.

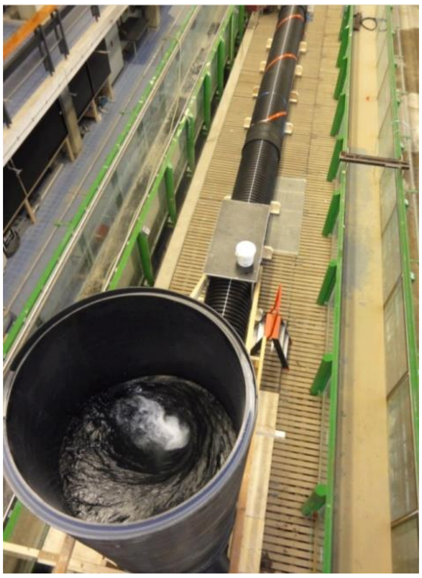

Figure 2: The SediPipe 600/24 operated in the lab at TU-Delft [1]

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 ($KMnO_4$).

Conclusions:

- The flow separator is working
- Dominant flow above the flow separator
- The flow separator is the essential feature to avoid 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).

For oil separation an additional upper flow separator has been introduced, which 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.

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

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 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.

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

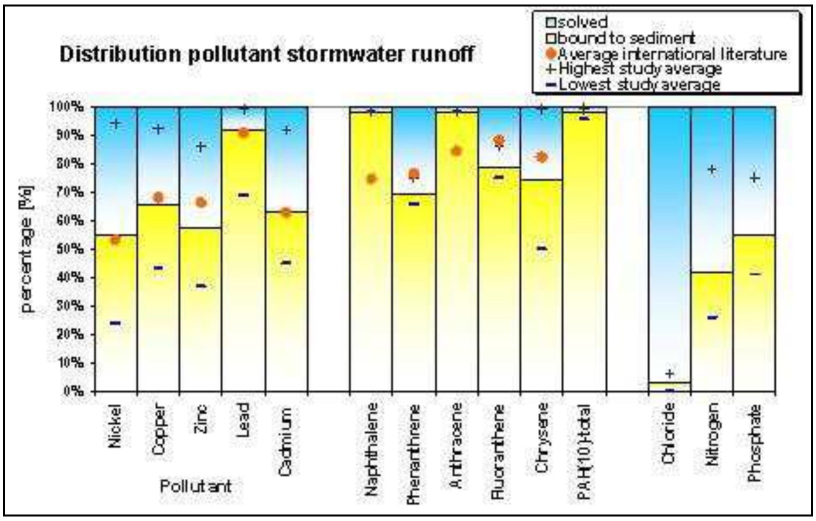

Figure 3: Percentage of bound and non-bound pollutants [2]

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)

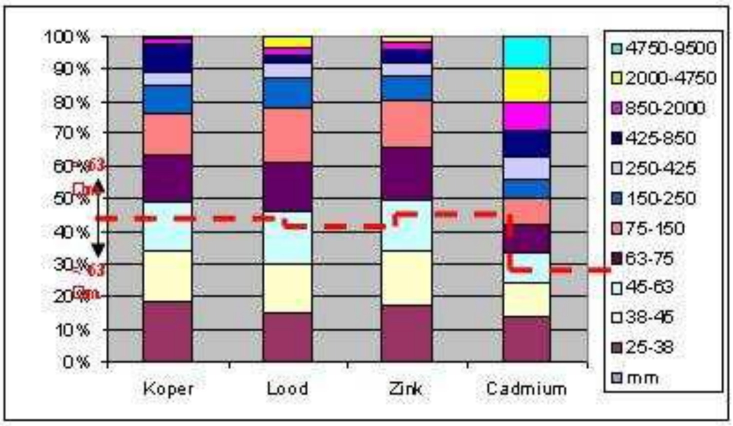

Figure 4: Several heavy metals and their bounding factors. (Copper, Lead, Zink and Cadmium) [2]

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.

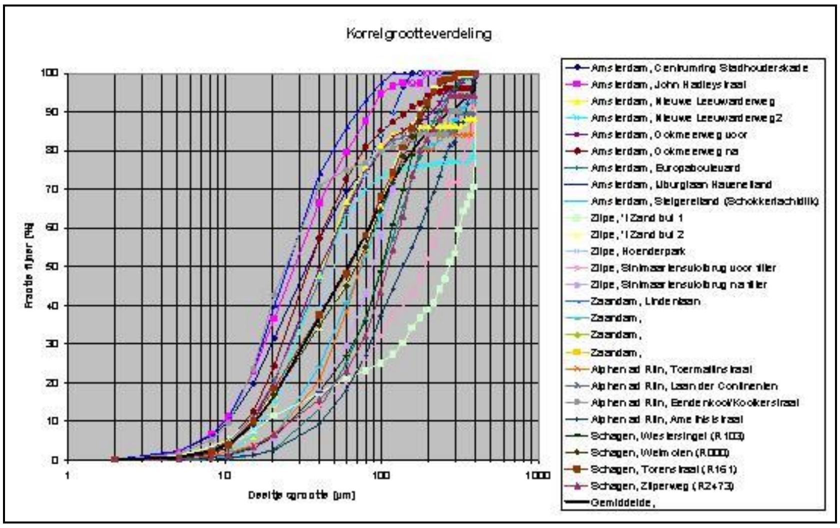

Figure 5: Particle sizes in the Netherlands. [2]

Millisil is a quartz material, silicon dioxide (SiO2), 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.

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 6: Sedimentation process – beginning [1]

Middle of the test: Depot already half filled with sediment

Figure 7: Sedimentation process – middle part [1]

Near end of the test: Depot almost filled with sediment

Figure 8: Sedimentation process – end part [1]

The test results (removal efficiency) of the SediPipe 6000/24:

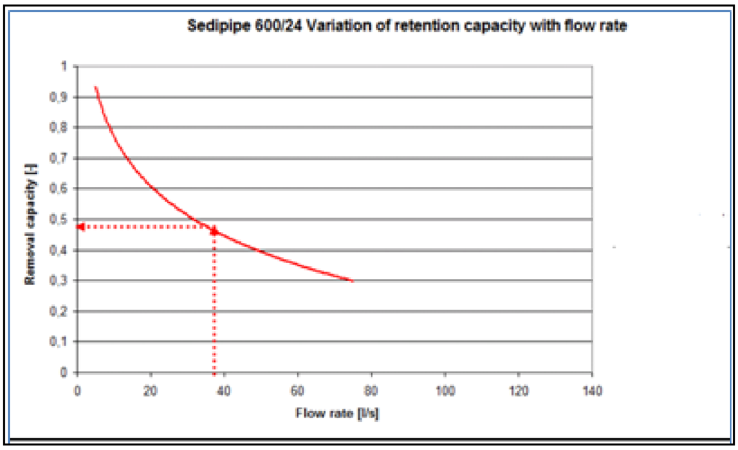

Figure 9: Removal efficiency for Millisil W4 of SediPipe XL 600/24 (with example at 37,5 l/s) both for scaled and real sized system [1]

Test results (removal efficiency) of the SediPipe 600/24 at IWS Leipzig:

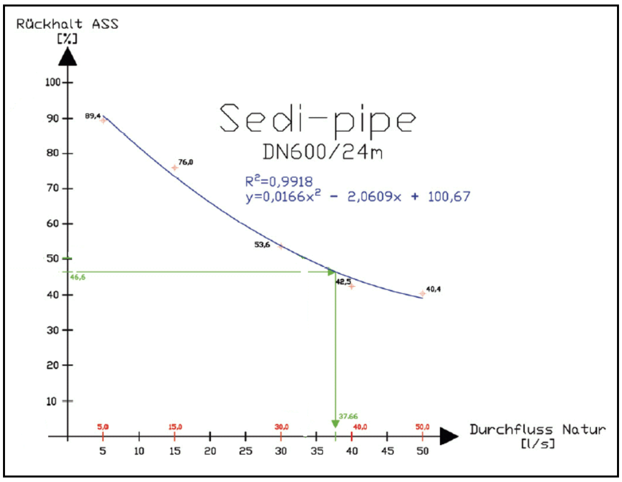

Figure 10: Test results of IWS Leipzig (SediPipe 600/24) [1]

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)

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 GUIDELINE

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].

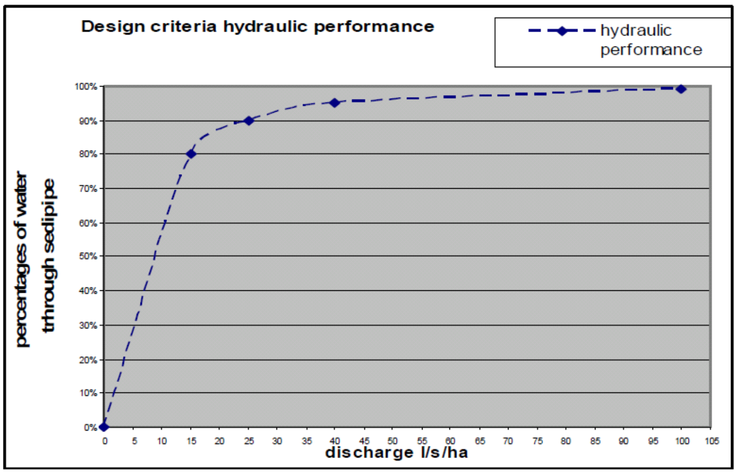

Figure 11: Statistical occurance of flow rates per hectare in the Netherlands [2]

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 for the Netherlands

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.

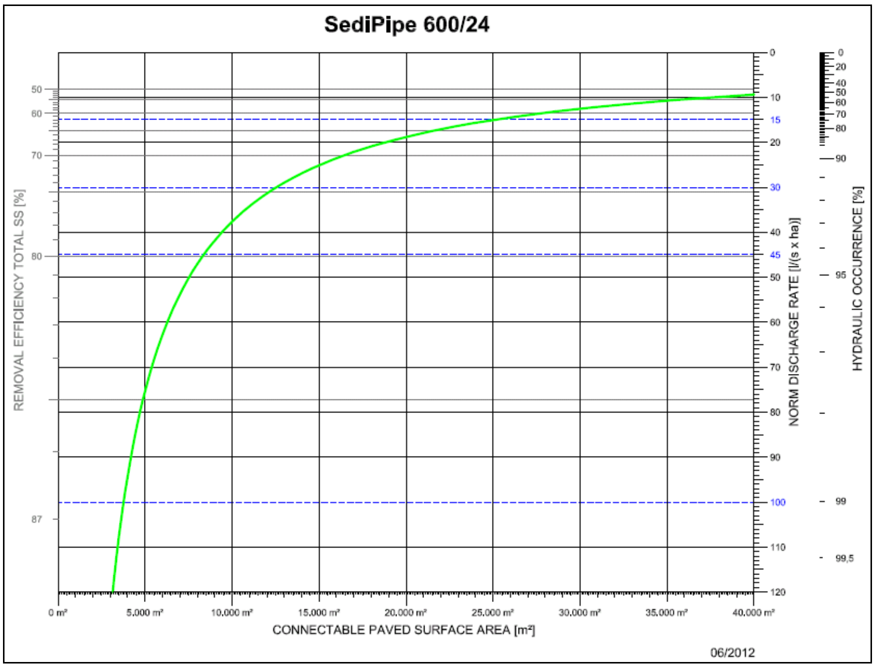

Figure 12: Design graph SediPipe 600/24 [1]

Table 2: Design table (complementary to the design graph) [1]

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

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.

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.

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.

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 for example 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 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.

LIST OF REFERENCES

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[2] ir. F.C. (Floris) Boogaard 2012, SKINT *Sustainable Urban Drainage systems research*, unpublished

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