Assessment basis for the 3P Hydrosystem for rainwater treatment

1. Assessment basis for filter pits

The filter pits which were developed, optimised and researched in multiple research projects are principally dimensioned according to three criteria:

1. the maximum through-flow quantity per time unit, important for:
    - the sedimentation in the hydrodynamic separator and the filter effect of the surfac and volume filters.
    - The maximum through-flow performance with usage of the internal (emergency) overflow (for strong rain events).
2. the necessary contact time of the water with the filter medium, important for:
    - the sorption of dissolved materials and mineral carbon dioxides on the inner filter surface.
    - The precipitation and surface precipitation of dissolved heavy metals in the filter.
3. the size of the sediment chamber, calculated from the expected load of solid particles.

2. Functioning principle the filter pit

The filter pit is made of polyethylene (image1). The rainwater from the drainable surface enters the pit on the lower end. Here sedimentation of particles and in particular of the sand fraction, takes place in a hydro-dynamic separator, because of turbulent secondary flows in a radial, laminar flow regime. These particles are collected, through an opening in the lower part of the filter pit, in a storage room (sediment chamber) at the bottom of the system which can be emptied through a discharge opening. In the middle of the filter pit is a filter element, which depending on area of application consists of specific porous medium. With this filter fine particles are filtered through the up-current procedure and the majority of dissolved particles is precipitated and adsorbate bound. The filter element can be back flushed from the top and in case of complete clogging can be exchanged. As the pit narrows toward the top the filter insert consist of multiple part, so that the filter can be lifted from the pit without problems and can be replaced. Life expectancy of the filter elements are as a rule between 2 and 5 years, depending on kind and structure of the connected area. The sediment chamber has to be vacuumed in intervals of one

to five years. It is variable in size and is adapted to the expected particle loads in the rain run-off.

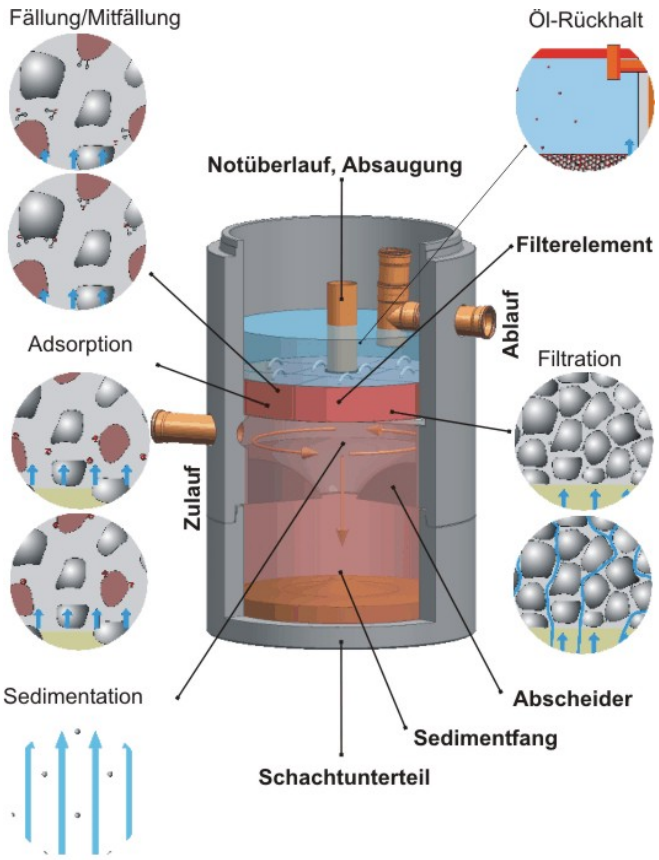

Image 1: Process inside of filter pit with hydro-dynamic separator

Image 2: System with 2 PE- filter pits in Hamburg, Bremer Straße

3. Hydraulic Calculation

The hydraulic calculation is not done site specific like for stormwater treatment systems as this alone is not sufficient. Furthermore the load of particles plays an equally significant role. Therefore pits were calculated on the basis of a rain station with relatively high rainfalls (mountain area, image 3), hence can be transferred to all rain stations with lower rainfall events.

Because of existing research results from a number of research projects (see project list) an area of 500 m^2 or 1000 m² (in dependence to the water that needs to be cleaned) was determined as maximum for the Hydrosystem 1000 and an area of 175 m^2 or 100 m² as maximum fof the Hydrosystem 400.

Combinations of multiple pits are possible.

T a	1		2		5		10		20		50	
	h_N	r_N	h_N	r_N	h_N	r_N	h_N	r_N	h_N	r_N	h_N	r_N
D	mm	l/(s·ha)	mm	l/(s·ha)	mm	l/(s·ha)	mm	l/(s·ha)	mm	l/(s·ha)	mm	l/(s·ha)
5 min	8,9	295,0	11,3	376,8	14,5	484,8	17,0	566,5	19,4	648,3	22,7	756,3
10 min	11,6	192,5	14,7	245,4	18,9	315,3	22,1	368,2	25,3	421,0	29,5	490,9
15 min	13,5	150,0	17,2	191,0	22,1	245,1	25,8	286,1	29,4	327,1	34,3	381,3
20 min	15,1	125,7	19,2	159,9	24,6	205,1	28,7	239,3	32,8	273,4	38,2	318,7
30 min	17,6	97,9	22,4	124,4	28,7	159,4	33,5	185,9	38,2	212,4	44,5	247,5
45 min	20,6	76,3	26,1	96,8	33,5	124,0	39,0	144,5	44,6	165,0	51,9	192,2
60 min	23,0	63,9	29,2	81,0	37,3	103,7	43,5	120,8	49,7	138,0	57,8	160,6
90 min	25,6	47,3	32,2	59,7	41,1	76,0	47,7	88,4	54,4	100,7	63,2	117,1
2 h	27,6	38,3	34,6	48,1	43,9	61,0	51,0	70,8	58,0	80,6	67,3	93,5
3 h	30,6	28,4	38,3	35,4	48,3	44,7	55,9	51,8	63,6	58,9	73,6	68,2
4 h	33,0	22,9	41,1	28,5	51,7	35,9	59,8	41,5	67,8	47,1	78,5	54,5
6 h	36,7	17,0	45,4	21,0	56,9	26,3	65,6	30,4	74,3	34,4	85,8	39,7
9 h	40,8	12,6	50,2	15,5	62,6	19,3	72,0	22,2	81,4	25,1	93,9	29,0
12 h	44,0	10,2	53,9	12,5	67,1	15,5	77,0	17,8	86,9	20,1	100,1	23,2
18 h	49,5	7,6	61,6	9,5	77,6	12,0	89,8	13,9	101,9	15,7	117,9	18,2
24 h	55,0	6,4	69,3	8,0	88,2	10,2	102,5	11,9	116,8	13,5	135,7	15,7
48 h	80,0	4,6	97,3	5,6	120,2	7,0	137,5	8,0	154,8	9,0	177,7	10,3
72 h	90,0	3,5	108,8	4,2	133,7	5,2	152,5	5,9	171,3	6,6	196,2	7,6

T - Wiederkehrzeit (in a): mittlere Zeitspanne, in der ein Ereignis einen Wert einmal erreicht oder überschreitet
D - Niederschlagsdauer einschließlich Unterbrechungen (in min, h)
h_N - Niederschlagshoehe (in mm)
r_N - Niederschlagsspende (in l/(s·ha))

Image 3: Rainfall statistic Feld 56,96 KOSTRA-DWD

T – Return time (in a): middle time span, in which an event reaches or exceeds a value once

D – Rainfall event duration including interruptions (in min,h)

hH – Rainfall height (in mm)

fH – Rainfall volumet (in l/(s x ha))

For the expected highest through-flow rates and a ten year return interval this means:

Table 1: Maximum through-flow rates through a filter pit with a traffic filter

Zeit min	Regen-spende l/(s·ha)	Durchfluss DN 1000 l/s	Durchfluss maximal l/s	Filterleistung maximal l/s	Filterleistung minimal l/s
5	566,5	28,3	30	12	2
10	368,2	18,4	30	12	2
15	286,1	14,3	30	12	2
20	239,3	12,0	30	12	2
30	185,9	9,3	30	12	2
45	144,5	7,2	30	12	2
60	120,8	6,0	30	12	2

Time (min) Rainfall volume Through-flow rate Filter performance

The filter performance in new condition with 25cm head is at least 12 l/s. Should performance be smaller than 2 l/s the filter needs to be flushed or replaced. According to current experiences this is the case at the earliest after 2 years. For roof run-offs without high sediment content the interval is greater.

For the performance of the filter and the hydro-dynamic separator especially rain events with mid-range intensity are of significance and not the big rain events. For the region Essen an evaluation of rain events results in:

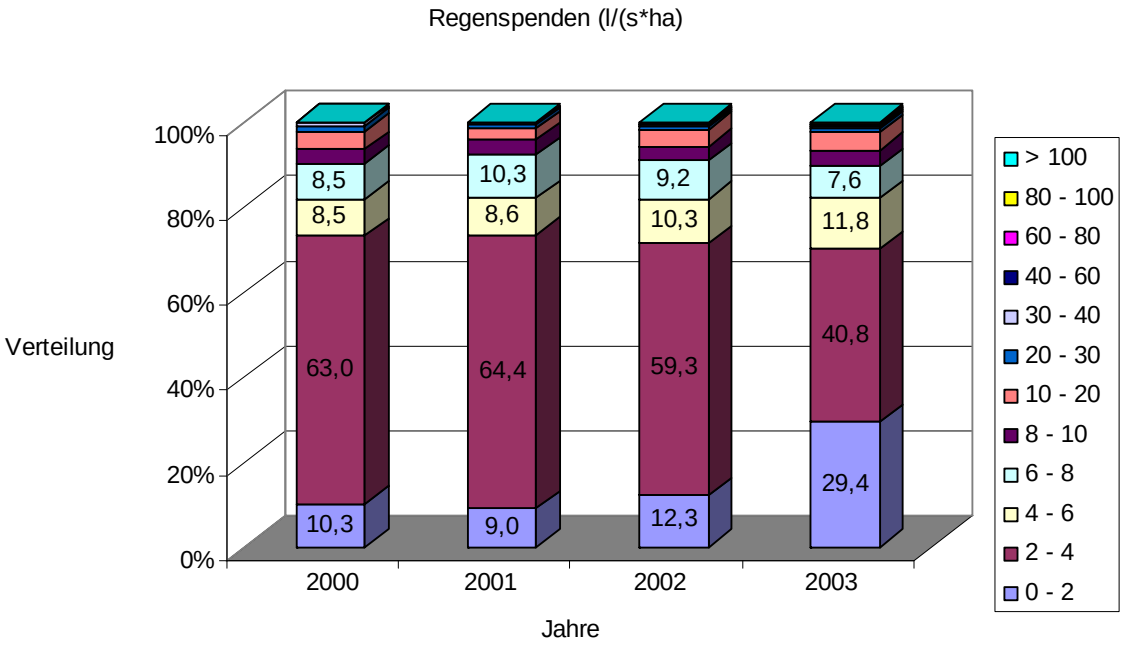

Image 4: Results of rain volumes from area Essen in l/(s·ha)

Regenspenden – rain volumes; Verteilung - distribution

From this concludes that most rain events show volumes between 2 and 4 l/(s x ha). If the filter pit can treat rain events up to 40 l/(s x ha) without overflow then more than 98 % of the rain run-offs are treated completely.

Table 2: Through-flow rate of different rain volumes in a pit DN 1000

Regen-spende l/(s·ha)	Durchfluss DN 1000 l/s
250	12,5
100	5,0
50	2,5
40	2,0
25	1,3
10	0,5
5	0,3

From the table one can read that the filter in new condition can completely treat 250 l/(s x ha). From a permeability of less than 2 l/s it needs to be flushed or exchanged. At this point in time it can still treat completely rains with 40 l/(s x ha). In this way it is ensured that more than 98 % of the rain volume is completely treated in the filter. After a static evaluation with a NA-Simulation at maximum 3 emergency overflows will occur per year, which will not significantly influence the performance rate of the system.

4. Material calculation

The material calculation depends on the expected pollutant material loads in the rain run-off. For this literature data from research projects was evaluated (ie. Göbel et al. 2006) and own data regenerated. For the physical and chemical function of the filter the contact time of the water with the filter medium is of significance. Image 5 demonstrates this with an example of Ortho-Phosphate in a traffic filter. This process is very slow in comparison to the retention processes for heavy metals, as it is almost exclusively based on precipitation reactions. For sorptive processes more than 90 % efficiency is achieved within the first 5 minutes.

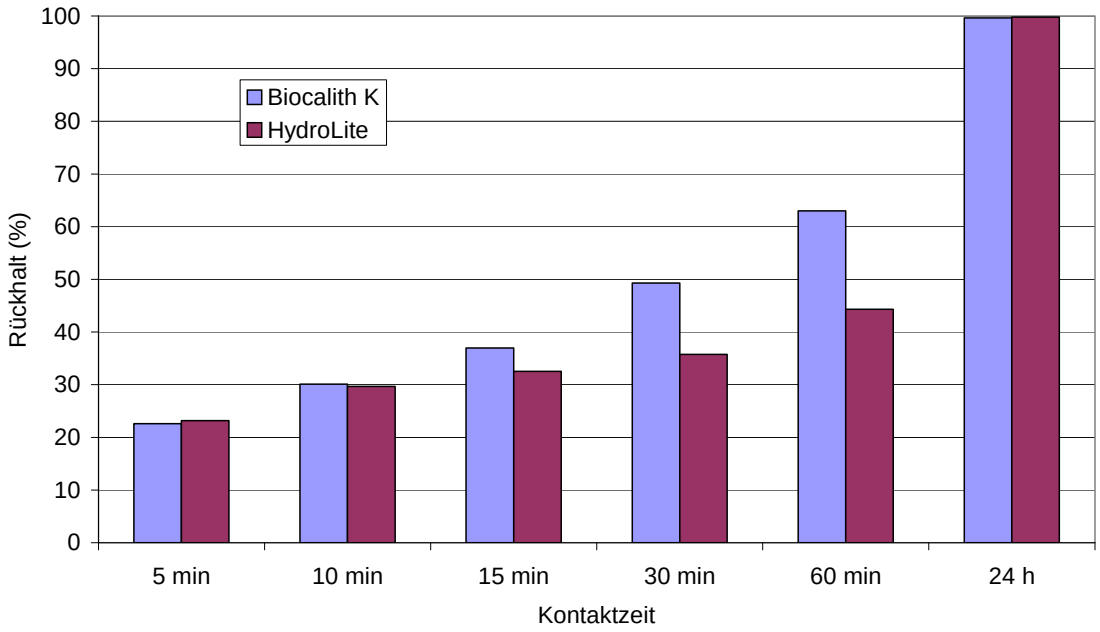

Image 5: Influence of contact time of water with two filter mediums for retention of Ortho-Phosphate

Table 3: Contact time of water with filter surface of Filter DN 1000

Regen-spende l/(s·ha)	Durchfluss DN 1000 l/s	Kontaktzeit mit Filter s	Kontaktzeit mit Filter min
25	1,25	90	1,5
20	1,00	113	1,9
15	0,75	150	2,5
10	0,50	225	3,8
5	0,25	450	7,5
3	0,15	750	12,5
1	0,05	2250	37,5

The contact time for Sorption with a majority of rain events should be at least 5 minutes.

5. Concetration aims and filter

The aimed concentrations for the systems were determined on the basis of the valid regulations. In particular the test values of the regulation for Federal Soil protection and waste depots on infiltrating water was used as the basis for the test values. Should higher run-off concentrations be permitted, so theoretically larger areas could be connected to the pits. This is currently being investigated in a research project.. Until we have closer details, the systems are calculated conservatively according to known parameters.

Table 4: Target values for medium run-off concentrations in comparison to expected inflow concentrations.

Stoff	Einheit	Dach allgemein		Kupferdach		Zinkdach		Parkplatz, Anliegerstraße		Hauptstraße		Zielvorgabe LAWA [1]	TrinkWV[2]	BBod SchV	Filter-schacht[5]
		von	bis	von	bis	von	bis	von	bis	von	bis	Grenzwert	Grenzwert	Prüfwert	Zielwert
Summenparameter												90-Perzentil			
elektr. Lf.	[uS/cm]	25	270	25	270	25	270	50	2400	110	2400	-	2500	-	< 1500
pH-Wert	[-]	4,7	6,8	4,7	6,8	4,7	6,8	6,4	7,9	6,4	7,9	-	6,5 - 9,5	-	7,0 - 9,5
Nährstoffe															
P ges	[mg/l]	0,06	0,50	0,06	0,50	0,06	0,50	0,09	0,30	0,23	0,34	-	-	-	0,20
NH_4	[mg/l]	0,1	6,2	0,1	6,2	0,1	6,2	0,0	0,9	0,5	2,3	-	0,5	-	0,3
NO_3	[mg/l]	0,1	4,7	0,1	4,7	0,1	4,7	0,0	16,0	0,0	16,0	-	50,0	-	[6]
Schwermetalle															
Cd	[÷g/l]	0,2	2,5	0,2	1,0	0,5	2,0	0,2	1,7	0,3	13,0	1,0	5,0	5,0	< 1,0
Zn	[÷g/l]	24	4.880	24	877	1.731	43.674	15	1.420	120	2.000	500	-	500	< 500
Cu	[÷g/l]	6	3.416	2.200	8.500	11	950	21	140	97	104	20	2000	50	< 50[4]
Pb	[÷g/l]	2	493	2	493	4	302	98	170	11	525	50	10	25	< 25[4]
Ni	[÷g/l]	2	7	2	7	2	7	4	70	4	70	50	20	50	< 20
Cr	[÷g/l]	2	6	2	6	2	6	6	50	6	50	50	50	50	< 50
Org. Summenparameter															
PAK (EPA)	[ug/l]	0,4	0,6	0,4	0,6	0,4	0,6	0,2	17,1	0,2	17,1	-	0,1 (6 Verb.)	0,2	< 0,2
MKW	[mg/l]	0,1	3,1	0,1	3,1	0,1	3,1	0,1	6,5	0,1	6,5	-	-	0,2	< 0,2

kritischer Parameter, Reinigung notwendig
in der Regel keine Reinigung notwendig, Einzelfallentscheidung
in der Regel unkritischer Parameter

[1] Zielvorgaben der Länderarbeitsgemeinschaft Wasser für das Schutzgut Oberflächengewässer, Nutzungsart Trinkwasser (1998)
[2] Grenzwerte der Trinkwasserverordnung (2001)
[3] Prüfwerte des Wirkungspfades Boden-Grundwasser nach §8 Abs. 1 Satz 2 des BBodSchGes (1999)
[4] bei Kupfer- und Bleidächern nur mit zweiter Behandlungsstufe zu erreichen (spez. Rohrrigole)
[5] die Zielvorgaben beziehen sich auf frachtgemittelte Jahresmittelwerte
[6] Nitrat ist mit dem Filter nicht signifikant zu reduzieren

The target values apply to all variants of filters. Currently filter mediums are used for four areas of applications:

1. Filter element roof für Regenabflüsse von herkömmliche Dachflächen
2. Filter element traffic for light loaded traffic area run-offs up to DTV approx. 5.000 cars/d.
3. Filter element metal for metal roos (copper, zinc, lead), or for run-offs with metal loads without salt.

4. Filter element heavy traffic for heavy loaded traffic area run-offs with DTV greater 5.000 cars/d and other similar run-off kinds.

Other run-offs can be tested individually in the laboratory with real water samples for their suitability to pollution removal.

6. Dimension of sediment chamber

The sediment chamber is so dimensioned that it can take in receiving solid particle loads for a time period of at least 2 years. For the DN1000 pit it is assumed: a connected area of 500 m^2, a run-off effective rain of 800 mm and a AFS of 150 mg/l for lightly loaded traffic areas and 300 mg/l for high loaded traffic areas. A calculation of this data is shown in table 5. For safety reasons the sediment component was increased by factor 1.5. For the pit DN 1000 this means that the sediment chamber needs to be 355 mm high. For security reasons it is doubled so that it is 750mm for this variant, and for lightly loaded traffic areas it is 500mm. The increase was largely done to consider input from materials used in winter services.

Table 5: Dimensioning of sediment chamber underneath of separator

Berechnung der Schlammfänge

	Verkehrsfläche DTV > 5.000 Kfz/d	Verkehrsfläche < 5.000 Kfz/d
Gesamtfläche	500 m^2	500 m^2
Abflusswirksamer Regen	800 mm/a	800 mm/a
Wasseranfall	400 m^3/a	400 m^3/a
AFS im Abfluss	300 mg/l	150 mg/l
Sedimentanfall	120 kg/a	60 kg/a
Zuschlagfaktor	1,50 -	1,50 -
Sedimentanfall	180 kg/a	90 kg/a
Schlammdichte	1,30 kg/dm^3	1,30 kg/dm^3
Schlammvolumen	138 dm^3	69 dm^3
Schlammfanghöhe (DN 1000)	178 mm	89 mm
Schlammfang für 2 Jahre:	355 mm	178 mm
Schlammfang gewählt:	**750 mm**	**500 mm**

For roof run-offs only about 50 mg/l AFS are expected, therefore the small sediment chamber with a height of 500mm is sufficient.

7. Research and Measurement projects

In the following projects filter pits are and have been researched:

1. DBU-Projekt, AZ 18622, Entwicklung und Optimierung der Filterschächte, Universität Münster, Prof. Coldewey, Förderung DBU
2. Akademie der Bildenden Künste München, Kupferdach, TU München, Prof. Wilderer, Förderung Bayerisches Landesamt für Umwelt
3. Altenheim Wahlscheid, Zinkdach, FH Bochum, Prof. Nolting, Förderung MUNLV-NRW
4. Mittlerer Ring München, Hauptverkehrsstraße, TU München, Dr. Helmreich, Prof. Horn, Förderung DBU AZ 22338
5. Aasee Projekt Münster, Einleitung aus Trennsystem, Uni Münster, Prof. Coldewey, Förderung Uni Münster, Stadt Münster
6. Vergleich mit Regenklärbecken in Wuppertal, Trennsystem, Uni Bochum, Dr. Pecher AG, Förderung über Betreiber
7. Bremer Straße, Hamburg, Autobahnzubringer, Messprojekt. in Zusammenarbeit mit der Behörde für Stadtentwicklung und Umwelt, Freie und Hansestadt Hamburg
8. Hertogstraat, Nimwegen, Verkehrsflächenabflüsse, Messprojekt der Stadt Nimwegen
9. Owasso-Basin-Project, USA, Trennsystem, Vergleich verschiedener dezentraler Behandlungsverfahren

8. Conclusions

Following current knowledge the following approach is on safe ground:

1. Hydrosystem 1000 traffic, heavy traffic and metal for maximum 500 m^2 connected area
2. Hydrosystem 1000 roof for maximum 1000 m^2 connected area
3. Hydrosystem 400 traffic, heavy traffic and metal for maximum 100 m^2 connected area
4. Hydrosystem 400 roof for maximum 175 m² connected area.

With this and selecting the right filter target concentration can be ensured.

For rain water treatment without infiltration probably larger areas can be connected, but this has to be confirmed through real measuring projects.

The filter pits should receive the general technical approval by the Deutschen Institutes für Bautechnik (DIBt) as soon as a test criteria is available at DIBt. A quality assurance according to new guidelines of the German institute for Quality and Labelling (Deutschen Institutes für Gütesicherung und Kennzeichnung e. V. (RAL) is also planned. The American approval according to TAPE-Protokoll of the State Washington was granted already in 2006.