SUSPENDED SOLID MANGEMENT IN URBAN SYSTEMS

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1 INTRODUCTION

According to recent mass balances in river systems, diffuse urban emissions (combined sewer overflows CSO und storm sewer outlets SSO) are one of the most important contributors to the overall pollution of German river systems. Figure 1 shows Zinc emissions into German surface water systems and the portion of different pathways for as average emission for the period 2006 to 2008.

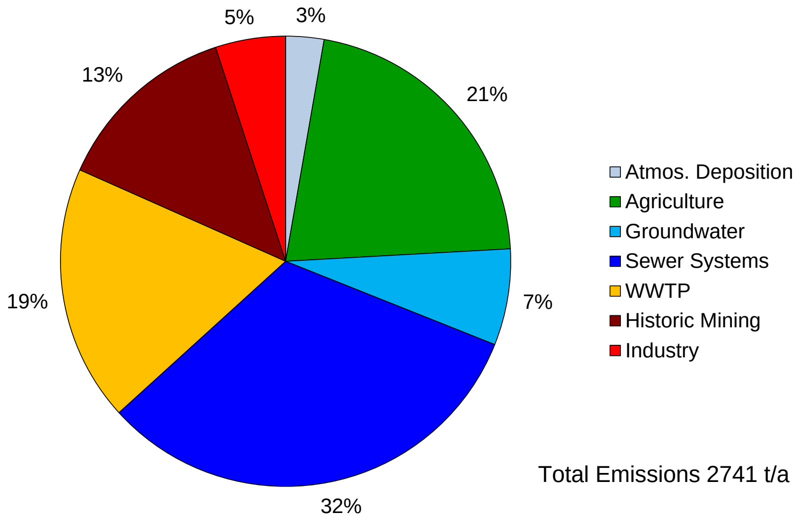

Figure 1 Zinc Emissions into German rivers systems (MoRE-Modellergebnisse, 2013, unveröffentlicht)

On the large scale about 32 % of the total zinc loads are caused by CSO and SSO. Municipal waste water treatment plants are contributing a further considerable share, so that in average around 50 % of the zinc load can be explained by urbanization and related activities. In this context, zinc is serving as an indicator since it is all around in urban areas (construction materials, tires, brake pad etc.) and therefore it can be quantified in all components of the urban environment. However, the result shown in figure 1 can be transferred to several further anthropogenic pollutants like PAH, DEHP. Thus, sewer systems can be identified as a predominate pathway of emissions of a number of anthropogenic pollutants associated to particulate matter.

The implementation of efficient methods for the storm water treatment aiming at suspended solid control is a general need both in combined and separate sewers.

2 SOLIDS IN SEWER SYSTEMS

2.1 Quantity of Total Suspended Solids

The design and operation of efficient facilities as well as the decision where they should be installed (de-central or central) requires suitable information about the quantity and quality of the total suspended solids (TSS) in urban systems.

Figure 2 illustrates the available database for Europe according to TSS concentrations observed in storm water outlets.

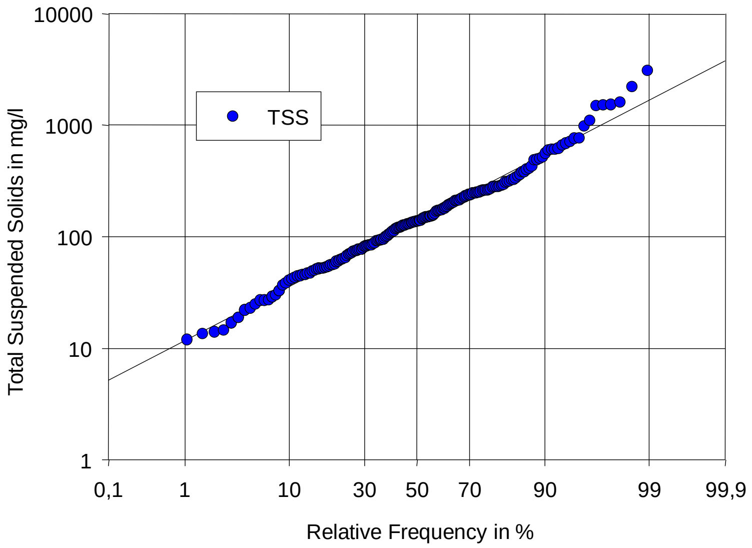

Figure 2 Distribution of observed TSS-concentrations in storm sewer outlets (data base Europe)

The range of concentrations shown covers three orders of magnitude and does not provide a suitable basis for the planning of efficient storm water management. However, the data are reflecting the given situation and a task of further data analysis is to reveal the reasons for the variability of the data depicted in figure 2. This requires comprehensive information regarding the boundary conditions prevailing in the different monitoring programs. Only for a few studies this information is available. However, based on own investigations in Berlin and some further well documented studies throughout Germany some general findings can be detected.

Table 1 shows the specific loads of TSS of different urban catchments. While, data in the first five lines are related to runoff mainly influenced by traffic activities, following studies are representing the results of storm water runoff monitoring carried out in larger urban catchments drained with separate sewer systems.

Table 1 Specific Total Suspended Solid loads in different catchments

Authors	Catchment	A_{imp} in ha	TSS in kg/(ha·a)
Pick et al. (2002)	Parking Lot	0.030	2512
Grottker (1987)	Street	0.410	2100
Nadler & Meißner (2004)	Street	0.001	1300
Lambert et al. (2009) [1)]	Highway	0.011	4560
Lambert et al. (2009) [1)]	Highway	0.018	5927
Fuchs et al. (2006)	Residential	90.0	1130
Grotehusmann et al. (2005)	Commercial	45.0	344
Terzioglu et al. (1987)	Residential	12.7	337
Lambert et al. (2005)	Residential	50.8	327
Schütte (2001)	Residential	14.1	305
Heinzmann (1993)	Residential	12.6	212
Grotehusmann et al. (2009)	Residential	23.0	103

1) Sample taken from 4 gullies in line

A wide range of specific loads becomes evident and the recalculation of average concentrations considering a specific annual runoff of 4000 $m^3/(ha \cdot a)$ results in concentrations between 26 and 1500 mg/l.

Nevertheless, the results shown along with additional information about the catchments and basic TSS properties allow identifying some general trends:

- High TSS loads typically occur in small catchments (single streets).
- High TSS loads imply that the solids comprise all grain sizes (clay to gravel) present on urban surfaces and transported by the runoff.
- A significant reduction of the TSS loads is often observed in larger urban catchments as a result of retention processes on the catchment surfaces and in the drainage systems.
- High TSS loads in larger urban catchments indicate the influence of vegetation.

Based on further detailed investigations (Fuchs et al. 2009) at different stage of the urban runoff process, a mass balance considering relevant losses of certain grain sizes was developed. In the frame of these studies the TSS were subdivided in two fractions:

- a coarse fraction comprising sand and gravel
- a fine fraction comprising clay and silt

This was the first essential step towards a more significant characterization of TSS. The resulting mass balance emphasises the boundary conditions and main objectives of storm water treatment at different position within the urban drainage system.

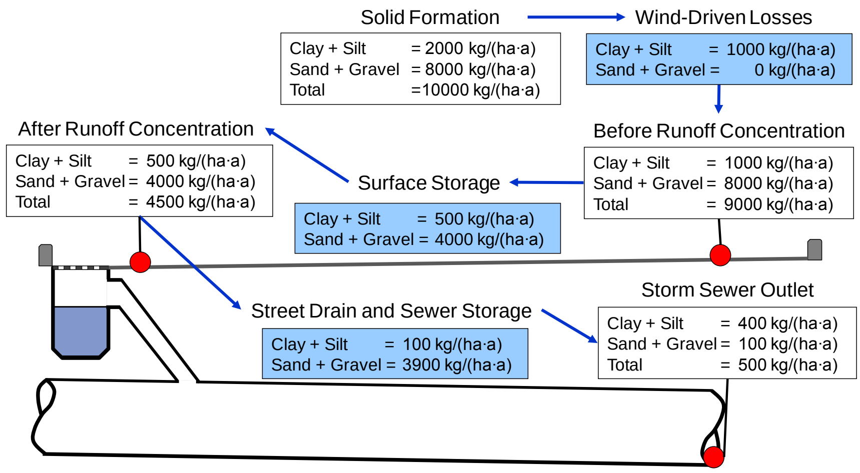

Figure 3 Mass balance for TSS in the urban environment

For 13 catchments, the solid loads transported with the storm water runoff were quantified separately for the coarse and fine fraction (Fuchs et al. 2009). As shown in figure 3 monitored TSS loads varied in a broad range between 500 and 10000 kg/(ha·a). Due to temporal retentions processes and subsequent street and sewer cleaning and the permanent deposition of solids on green areas a significant reduction of TSS takes place.

More important for storm water treatment is the change observed in the share of the coarse and fine fractions. While the coarse material is dominating TSS loads at the beginning of the transport process, the TSS at the storm sewer outlets predominantly consist of fine particles. At the outlet of an extended drainage system, the TSS load is rather constant and varies only between 200 and 400 kg/(ha·a) or between 50 and 100 mg/l respectively. Higher loads are the result of a certain amount of coarse material.

2.2 Quality of Total Suspended Solids

In order to understand the main processes affecting solids transport in urban systems as well as to implement efficient treatment methods it is necessary to differentiate the TSS in a coarse(sand and gravel) and a fine (silt and clay) fraction at least.

Besides the grain size distribution, suspended solids in storm water runoff need to be analysed for their organic volatile compounds. This parameter allows the assessment of both pollutant transport capacity and treatment options. The grain size distribution is usually determined by sieving analysis. Therefore, the terms clay or sand refer to the solids showing a certain grain size. This does not necessarily mean that the particles have chemical and physical properties of clay or sand.

Table 2 shows the representative results for the loss on ignition (LOI) and pollutant loading of fine and coarse solids. The data correspond to a single catchment but the general message is transferable to all catchments under consideration.

Table 2 Properties of different particles in storm water run off

	Clay and Silt	Sand and Gravel inorganic	Sand and Gravel organic
LOI in %	40.0	2.50	90.0
P_{tot} in g/kg	2.90	0.20	0.86
Zn_{tot} in mg/kg	2915	150	1169
Fe_{tot} in g/kg	25.9	5.00	8.81

The fine particles in the grain size of clay and silt are consistently highly polluted and thus the target of storm water treatment. In contrast to this, the coarse material has to be distinguished into two fractions. While the inorganic proportion is rather unpolluted, the organic proportion (vegetation debris) shows a pollutant loading similar to the fine particles. Another important aspect in regard to this fraction is that it is subject of constant transformation processes through which the material changes from formally coarse to fine particles.

According to these results, the efficient removal of the fine particles and -when present- of the coarse organic fraction can be defined as the primary aim of storm water treatment.

3 STORM WATER TREATMENT

Storm water management comprises both measures to avoid or to reduce runoff and treatment. The technologies available for the latter are sedimentation and filtration which may be realized as centralized plants or de-centralized units.

3.1 Sedimentation tanks

In the past sedimentation tanks were most commonly installed. The effectiveness of these tanks is still a controversial. However, recent studies (Fuchs et al., 2013) show that the efficiency of sedimentation tanks is weak if it considers the removal of fine particles and pollutants adsorbed to them as to the target. For standard settling tanks that are dimensioned on the basis of a maximum surface load of 10 m/h, the reported suspended solids removal rate ranges between

0 and 30 %. This results mainly from remobilization processes occurring during single events at which the maximum surface load is reached.

Lamella settler could help to overcome the shortcomings of standard settling tanks by increasing the given surface area significantly. Considering a maximum surface loading rate of 4 m/h the effect of remobilization can be minimized and the lamella settler can reach up 70% TSS removal.

3.2 Soil Filter Systems

Within the last 15 years filtration processes have been implemented to meet increased requirements set out for sensitive receiving waters. These soil filter systems show an excellent TSS removal efficiency. The observed removal rates reach up to more than 90 % and the almost quantitative retention of particles results in a high efficiency for several anthropogenic pollutants attached to the fine particles. As soil filters systems encompass biological treatment processes they reduce the COD and ammonia load significantly. However, soil filter systems are demanding in design and operation. For instance, the filter surface takes around 1 % of the connected catchment area so that the application is restricted especially in highly urbanized zones.

3.3 De-centralized Systems

Decentralized or near to the source treatment systems were developed to overcame the given limitations of large sedimentation and filtration plants. They comprise usually different processes like sedimentation, filtration and adsorption in a single unit. Some of them are tested under laboratory conditions and the principle functioning of the system is certified. Point of use technology may be a single roof drain or a street gully. Particularly, the application of latter bears some unsolved problems. In reference to figure 3 the treatment system installed in a gully has to handle a potential TSS load of 4500 kg/(ha·a). Even if it is considered that the catchment area connected to a single gully covers only an area of 400 m^2, the TSS load which has to be removed and stored safely is 180 kg/a. Such high loadings result in an increased effort of operation control, high operation costs and increases the probability of failure.

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Suspended Solid Management in Urban Systems

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Outline

- Introduction
- Data on Quantity of Solids in Urban Systems
- Data on Quality of Solids in Urban Systems
- Storm Water Treatment Technologies
- Summary and Conclusion

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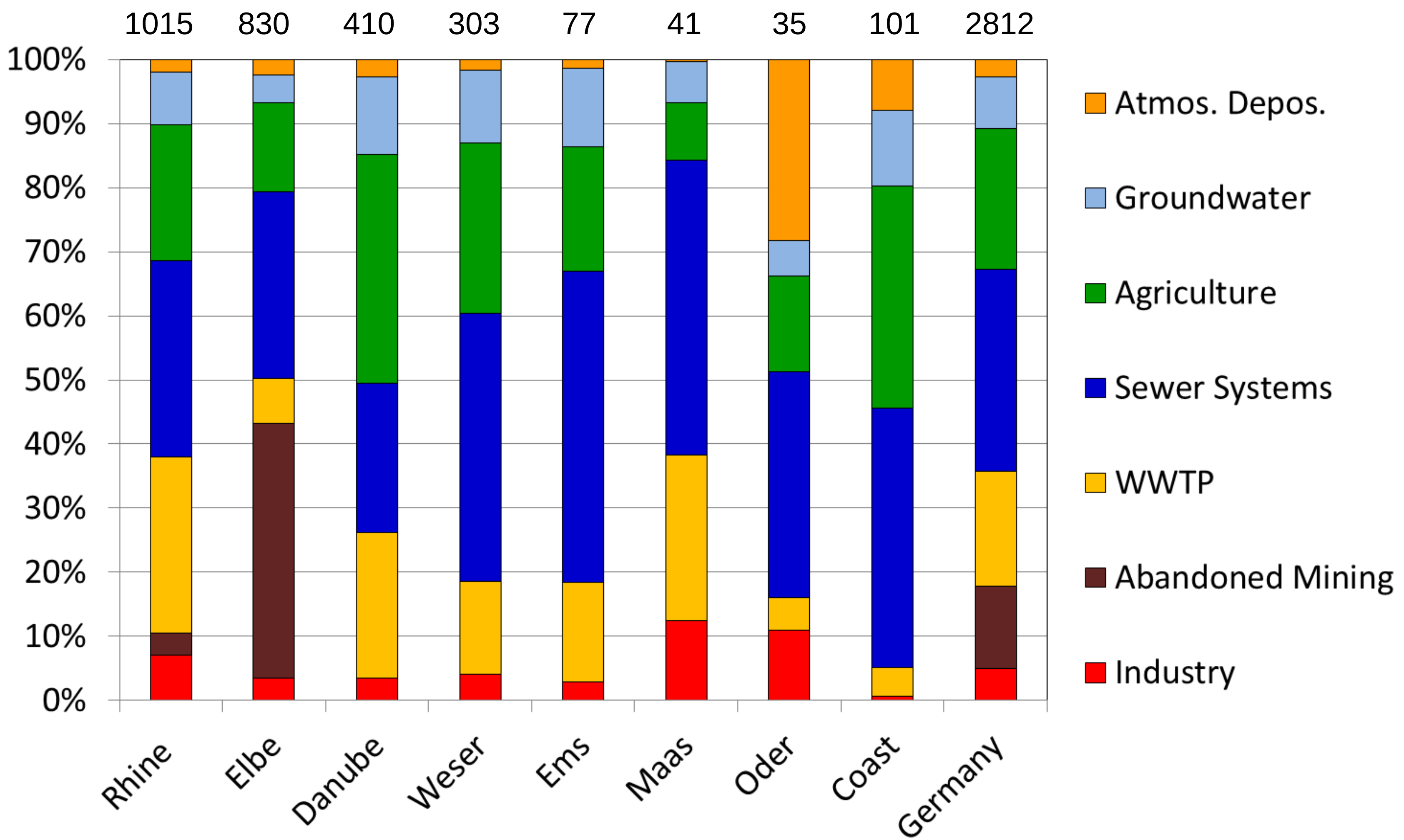
Introduction

Zinc Emissions into River Systems in t/a



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Specific TSS Loads from Urban Areas

Karlsruhe Institute of Technology

Literature	Sub-catchment	A_{imp} in ha	TSS in kg/(ha·a)
Lambert et al. (2009)	A 113 neu	0.018	5927
Lambert et al. (2009)	A100	0.011	4560
Pick et al. (2002)	Höxter	0.030	2512
Grottker (1987)	Hildesheim	0.410	2100
Nadler u. Meißner (2004)	Augsburg	0.001	1300
Grotehusmann et al. (2005)	Adlershof	45.0	344
Terzioglu et al. (1987)	Wilmersdorf	12.7	337
Lambert et al. (2005)	Biesdorf	50.8	327
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Share of Fine and Coarse Solids

Catchment	TSS mg /l	LOI %	Share %	TSS mg /l	LOI %	Share %
	Clay and Silt, < 63 µm			Sand and Gravel, 63 µm – 2 mm		
Berlin 1	153	31.7	87	14	38.3	13
Berlin 2	98	24.7	97	3	40.3	3
Berlin 3	91	26.3	88	12	55.6	12
Rastatt	92	28.1	72	26	51.4	28
Oberbruch	106	15.7	94	5	27.6	6
Pforzheim	98	25.3	71	44	44.1	29

- Fine particles show a rather constant concentration between 70 and 150 mg/l
- Coarse particles show a wide range of concentrations, starting from zero up to many thousands mg/l
- At storm sewer outlets of extended catchments fine particles are prevailing

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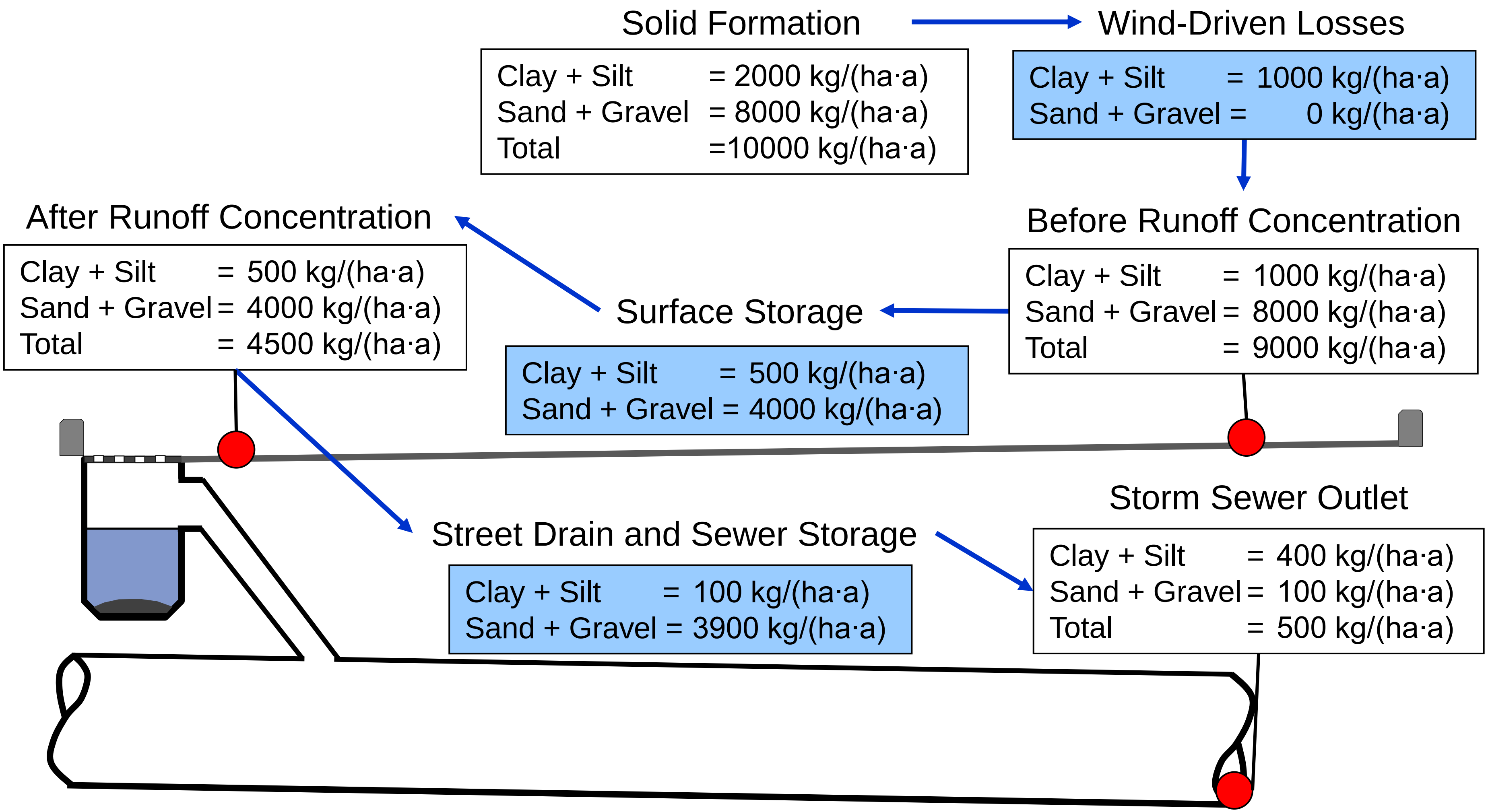
Losses and Classification of Urban Solids



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Sinks of Urban Solids

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Origin and Quality of Urban Solids

Sand and Gravel > 63 µm

8 % Elementary Iron

Clay and Silt < 63 µm

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Pollutant Loading of Urban Solids

Parameter	Clay and Silt	Sand and gravel inorganic	Sand and gravel organic
LOI in %	40.0	2.50	90.0
P_{tot} in g/kg	2.90	0.20	0.86
Zn_{tot} in mg/kg	2915	150	1169
Fe_{tot} in g/kg	25.9	5.00	8.81

- Fine particles are always highly polluted
- Coarse inorganic particles are less or even unpolluted
- Coarse organic particles are showing a pollutant level similar to the fine

- Urban solids are rich in iron, iron oxides and iron hydroxides
- Urban solids may contain considerable portions of organic substance
- Urban solids tend to coagulate and create a considerable oxygen demand

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Basic Technologies for Storm Water Treatment

Standard Operations

- Sedimentation
- Filtration

Special Operations
(not applicable for storm water treatment)

- Adsorption and Ion Exchange
- Flotation
- Flocculation

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Efficiency of Sedimentation Plants

- Boundary conditions
  - High share of fine solids in the influent 70 – 90 %
  - Rather constant loads 300 – 500 kg/(ha·a)
  - Permanent impounding is counter productive
  - Salt application impair sedimentation

- Standard sedimentation tanks
  - Low efficiency if dimensioned for a SLR of 10 m/h
  - TSS removal rate varies between 0 – 30 %
  - Pollutant removal rate tends to zero

- Lamella settler
  - Good efficiency if dimensioned for a SLR of 4 m/h
  - TSS removal rate varies between 50 – 70 %
  - Pollutant removal rate shows similar values
  - Demanding hydraulic conditions

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Efficiency of Filtration Plants

- Soil filter systems
  - High share of fine solids in the influent 70 – 90 %
  - Rather constant loads 300 – 500 kg/(ha·a)
  - TSS removal rate reaches 95 %
  - High efficiency for particulate pollutants
  - Sediments create a regenerative pollutant sink
  - High space requirements and demanding design and operation

- De-centralized filter and sedimentation systems
  - Highly variable grain size distribution the influent (fines 10 – 50 %)
  - Site specific loads extremely variable up to 4500 kg/(ha·a)
  - Pollutant removal potential is high
  - Distinct hydraulic limitations
  - Very sensitive for salt or peak concentrations
  - High operation and maintenance cost

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Summary and Conclusion

- Solids emitted by urban sewer systems are responsible for a significant share of surface water pollution
- Measures to reduce the overall pollution are thus to be implemented in urban areas
- The implementation of efficient measures requires detailed knowledge about the masses and properties of urban solids
- Solids have to be subdivided into a coarse and a fine fraction and characterized in regard to their organic and iron content
- Concentrations of fine particles are rather constant, they are the primary aim of storm water treatment
- Concentration of coarse material is highly variable, they are not in the focus of storm water treatment
- The transport and retention processes on urban surfaces are defining the requirements for centralized or de-centralized measures

- All measures reducing surface run off are most effective

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