Optimizing SUDS by transnational knowledge exchange - guidelines for the design & construction and operation

Optimisation des systèmes durables de gestion des eaux pluviales urbaines par l'échange de connaissances transnationales - Recommandations pour la conception, la construction et le fonctionnement

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RÉSUMÉ

L'échange transnational de connaissances joue un rôle important dans la dissémination des informations sur la mise en œuvre de systèmes durables de gestion des eaux pluviales urbaines (SUDS) dans le monde entier, cependant les échanges transnationaux structurés sont actuellement sous-utilisés de ce point de vue. Le projet d'intégration des compétences et des nouvelles technologies (SKINT) prend en compte cette réalité, en insistant sur le besoin d'un langage multidisciplinaire en vue d'intégrer les domaines de la planification urbaine et de la gestion de l'eau. SKINT encourage la mise en œuvre dans la région de la Mer du Nord de solutions techniques innovantes et durables qui ont déjà été des succès. De plus, il encourage leur adaptation pour des applications dans des conditions différentes de celle pour lesquelles elles avaient été conçues à l'origine.

L'échange transnational de connaissances est essentiel pour améliorer la prise de conscience des performances des SUDS dans différents pays ou conditions. Le système Mulde Rigole est un excellent exemple qui, après plusieurs années d'utilisation en Allemagne, est arrivé aux Pays-Bas en 1997 et a été mis en œuvre sous le nom de « Wadi ». Suite à des échanges transnationaux de connaissances, les premières étapes de mise en œuvre de ce type de mesures sont en cours en Grande Bretagne.

ABSTRACT

Transnational knowledge exchange plays an important role in spreading information about and implementing SUDS around the world, but structured transnational exchange is currently underutilized in this repect. This is recognized in the project Skills Integration and New Technologies (SKINT) which emphasizes the need for speaking a multi disciplinary language to integrate the worlds of spatial planning and water management. SKINT encourages the implementation of innovative technical and sustainable solutions around the North Sea Region which have already proved to be successful. It also encourages their adaptation for application in circumstances different to those for which they were originally conceived.

Transnational knowledge exchange is essential to raise the awareness of the performance of SUDS in different circumstances or countries. A good example is the Mulde Rigole system that after many years of use in Germany found its way into the Netherlands around 1997 and was implemented under the name 'Wadi'. As a result of transnational knowledge exchange, the first steps of establishing this type of measure are now being taken in the UK.

KEYWORDS

Transnational knowledge exchange, innovative SUDS, stormwater quality, maintenance, design, monitoring, removal efficiency, partitioning of pollutants

INTRODUCTION

Although the concepts of sustainable urban drainage systems (SUDS) are widely understood little attention is given to how to optimize these systems to improve the hydraulic benefits and removal efficiency of SUDS to achieve quality standards or other aspirations. The European Water Framework Directive (WFD) demands an enhanced protection of the aquatic environment. As a consequence, the WFD requires municipalities to address the emission from wastewater systems properly and to take action when these emissions affect the quality of receiving waters. Sustainable Urban Drainage Systems (SUDS) which can play an important role in achieving that goal include: infiltration trenches and basins, (slow) sand filters, soakaways, ponds, swales, wetlands, bio-retention, filter strips, sedimentation basins, (lamella) filters, lava filters and pervious pavements.

The implementation of SUDS in the Dutch densely populated polders (low-lying tracts of land with generally high groundwater tables and low permeable soil enclosed by embankments ‘dikes’) requires specific guidelines for design, construction and maintaining to prolong the lifespan of SUDS. However, the techniques used in the Netherlands can also be used in the more undulating landscapes, within many regions of the UK, providing flood risk management opportunities to the list of water quality applications that is already well established.

Over the years, different countries have developed their own knowledge bases for the implementation of SUDS. The following list provides a short illustration of the growing volume of guidance available

- Germany (DWA)
- United Kingdom (CIRIA)
- Belgium (VLARIO)
- Netherlands (RIONED)

In this paper we focus on the process that resulted in such guidance within the Netherlands, but this is not dissimilar to what has happened in other countries. Comparing different approaches in Europe the Dutch focus more on the quality aspects whereas currently within parts of the UK more focus lies on quantity aspects to control runoff and reduce urban flood risk.

Useful information is gathered by interviewing several organizations that are occupied with designing, constructing and maintaining SUDS. The implementation and development of these SUDS has been studied in order to optimize their performance to prevent dis-investments and to improve the transnational exchange of knowledge and experience (SKINT, 2009).

1 THE DUTCH APPROACH: STORMWATER QUALITY

1.1 Introduction

In the Netherlands many SUDS systems have been studied in detail in order to provide guidance for development and implementation. Knowledge gaps have been filled by research involving on site monitoring and laboratory testing. In common with other countries the Dutch authorities seem to have a need for SUDS to minimize the emissions of storm water to effect the water quality of receiving waters (WFD). To estimate the impact of storm water on the environment and the required removal efficiency of SUDS several measurements of the quality of storm water have been placed in a storm water quality database.

Currently about 75% of the Dutch municipalities have local projects in which the storm water has been disconnected from the combined sewer and discharged to the surface water. Figure 1a shows the extent to which strormwater is managed using (combined) sewer systems in the Netherlands. Like in other European countries several local authorities had a different approach on the implementation of SUDS and regulation within disconnecting projects. Questions were raised about the sustainability of disconnecting stormwater regarding the discharge of possible polluted stormwater to groundwater and surface water; what is the quality of storm water in the Netherlands?

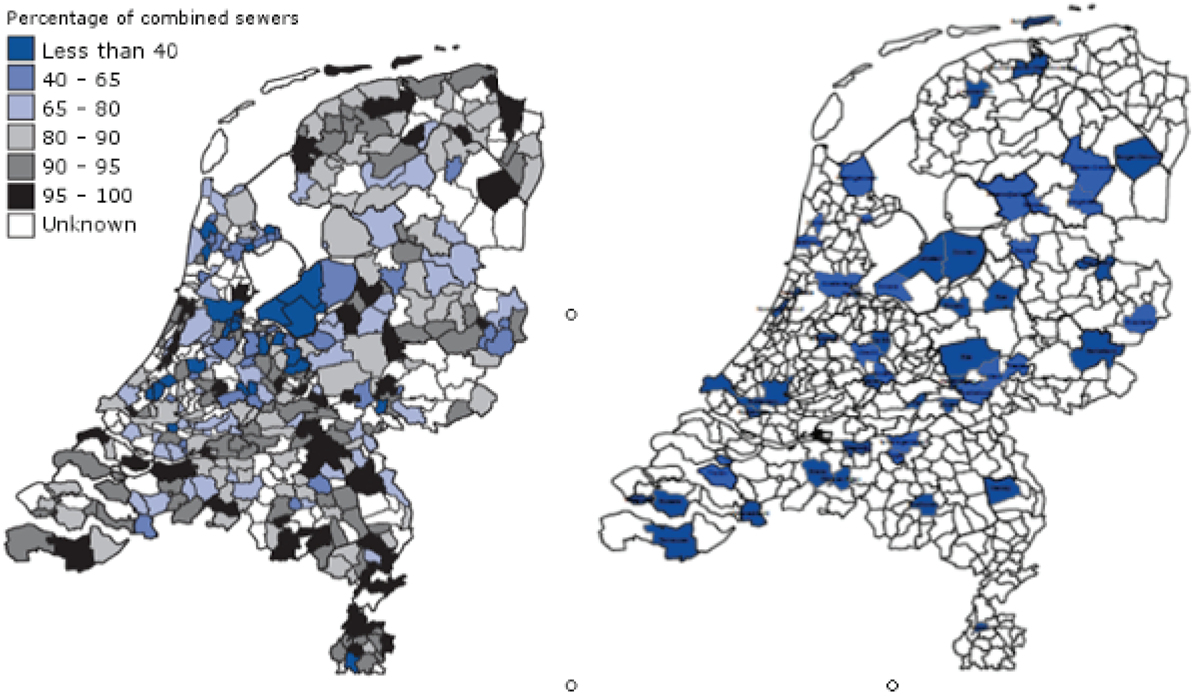


Figure 1a Dutch situation sewer systems (RIONED, 2009), Figure 1b research locations of stormwater quality (SKINT, 2009)

1.2 Dutch Storm water quality database

The Dutch storm water database has been developed to draw together the results of a considerable amount of research over recent years (figure 1b). It comprises over 7500 measurements in Holland and is complemented by several measurements from nearby countries in Europe. The concentrations of several contaminants are documented as well as the percentage adsorbed contamination to suspended solids. Research documents are collected to get detailed descriptions of the aims of the measurements and of the methods used and other information which can influence the quality of storm water. These include information on the frequency and methods of maintenance of the area and the specific materials that are used on roofs and roads.

The quality of storm water varies greatly but in general an indication of the run-off quality can be achieved by selecting the category of the connected area (industrial, residential, commercial). Some of the measured concentrations in urban areas (roofs and roads) are given in table 1.

The concentrations of the contaminations in the database have been compared to Dutch quality standards for surface water (Maximum Risk ‘MTR’). From this point of view some heavy metals (copper, lead and zinc), some PAHs, nutrients (P_{total} and N_{kj}) and E.coli are considered to be contaminants that should be addressed to by SUDS.

Table 1 concentrations in urban areas (roofs and roads)

	Cu	Pb	Zn	PAHs	BOD	COD	Ptot	Ntot	Ecoli
	µg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	mg/l	kve*10^3/100 ml
mean	19	18	102	0,8	5,7	32	0,4	1,9	1,9E+04
median	11	6	60	0,8	3,1	20,0	0,3	1,1	6,7E+03
90 percentile	35	43	250	1,1	12,5	60	1,0	3,1	3,5E+04
Number of measurements	686	682	684	145	219	681	107	590	116
Quality standard ‘MTR’	3,8	22	40	4,3	-	-	0,15	2,20	1

High concentrations on nutrients (P_{total} and N_{kj}) and E.coli can find their origin in foul connections of wastewater to the stormwater sewer.

Foul connections

Figure 2: Stormwater drainage system with foul connections (left), connection of bathroom on a rainwaterpipe and stormwater drainage system (right).

The effect on the water quality of tracing foul connections is shown by model calculations: If for example 2% of the sanitary connections dispose on the storm water sewage, the pollution of the surface water will be roughly equal to the pollution out of a combined system. Tracing foul connections on a random per plot level is a costly, uncertain and time-consuming process, especially if residents are to be involved. Existing methods of testing all drains per plot by smoke or colored fluids is labor and cost intensive. In several municipalities cost effective methods has been researched which shows that temperature (and acoustic) measurements in the storm water sewage give a good insight into the presence or absence of foul connections. Based on this methodic it is possible to indicate where measures are cost-effective to reduce the disposal to the surface water by foul connections. After tracing and fixing foul connections, temperature measurements can be used to continuously monitor the sewage to make sure no new foul connections emerge.

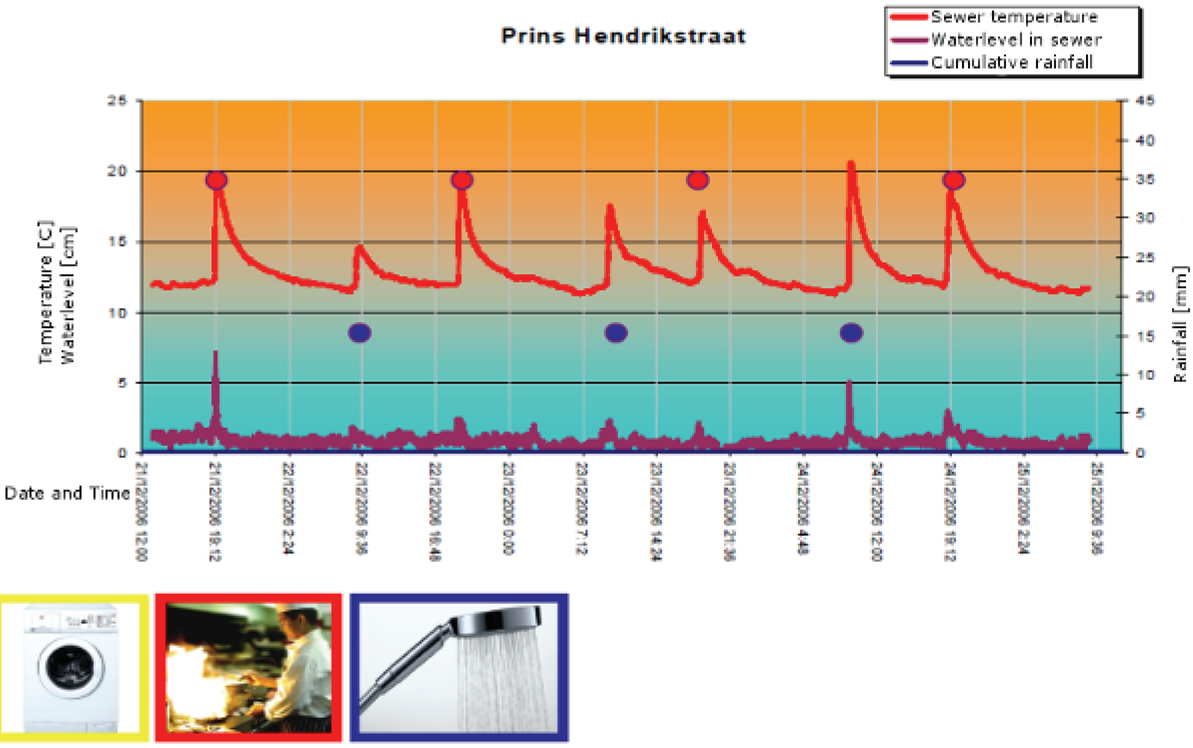


Figure 3 temperature changes in stormwater drainage system in Egmond aan Zee due to foul connections.

Figure 3 shows a conduit with at least one wrong connection. During the period without rainfall the temperature peaks are very clear. The peaks in temperature appear each morning at about 8 o'clock (showers) and at the end of the afternoon during dinnertime.

1.3 Dutch research on SUDS

In order to achieve Dutch quality ambitions there are a large variety of SUDS to choose from such as; infiltration trenches and basins, (slow) sand filters, soakaways, ponds, swales, stormwater wetlands and bioretention, filter strips, sedimentation basins, (lamella) filters and pervious pavements.

Several organizations were interviewed to determine the lack of knowledge. One of the topics was *'which criteria do you use to determine the selection of SUDS'*, the most given criteria are:

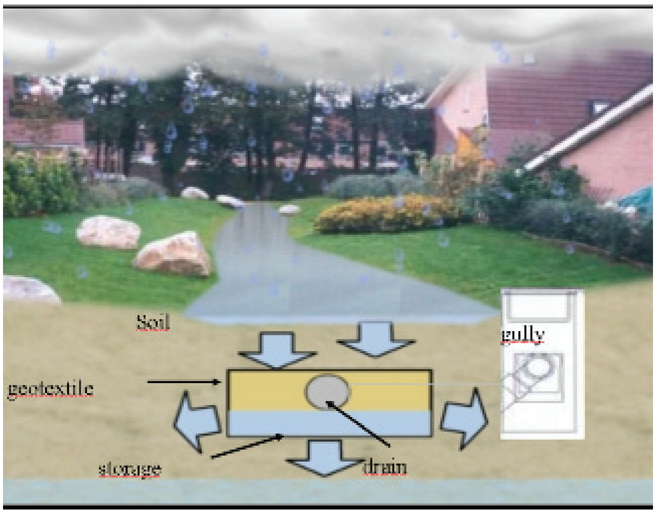
1. removal efficiency,
2. cost (building and maintenance),
3. required space,
4. experience maintenance
5. esthetical
6. robustness
7. life cycle analyses
8. sustainability

Several experiences from designing, building and maintaining suds are gathered by (inter-)national literature review, interviews and fieldtrips. The required removal efficiency can be calculated with the database-tool. From several monitoring projects of storm water wetlands, (slow) sand filters, swales, sedimentation basins and (lamella) filters the removal efficiency as well as the cost of building and maintaining SUDS were collected.

In the enquiry, design standards are evaluated which indicate the amount off space that is needed to achieve the required removal efficiency for spatial planners. Examples of successful implementations of SUDS are documented in fact sheets with the most important features to stimulate the use of SUDS. In order to stimulate transnational knowledge about SUDS for the project SKINT these documents will be translated a reviewed in an international perspective.

Figure 4 Dutch guidebook designing, building, maintaining and monitoring SUDS

2 INTRODUCTION OF SUDS BY TRANSNATIONAL KNOWLEDGE EXCHANGE



The project Skills Integration and New Technologies (SKINT) encourages the transnational knowledge exchange and implementation of innovative technical and sustainable solutions around the north sea region which have already proved to be successful. Before transnational implementation of systems it is advised to have knowledge of the development of the system.

An example of this is the Wadi-system (picture). All runoff water from paved areas and roofs in Ruwenbos is transported via open gutters to a separated system of three 'Wadis' traversing the area. A Wadi is a u-shaped green ditch which sits above a drainage element. In normal operation the water in the ditch seeps down into the drainage element and then soaks away into the ground. During periods of prolonged or heavy rainfall, the water ponds within the ditch and overflows through a high level gulley into the drainage element. If the infiltration capacity of the system exceeded the excess runs through a drain into a retention pond. The water in the Wadis is stored to a level of approximately 0,3 meters, when the gulley starts to operate. This should only occur once in every two years. When the total capacity of the system is exceeded the water flows overland to the retention pond by means of a designed pathway. The Wadi and the retention pond provide recreational amenities for the residents. The conceptualization, development, evaluation and implementation of the Wadi system in the Netherlands is illustrated in figure 5.

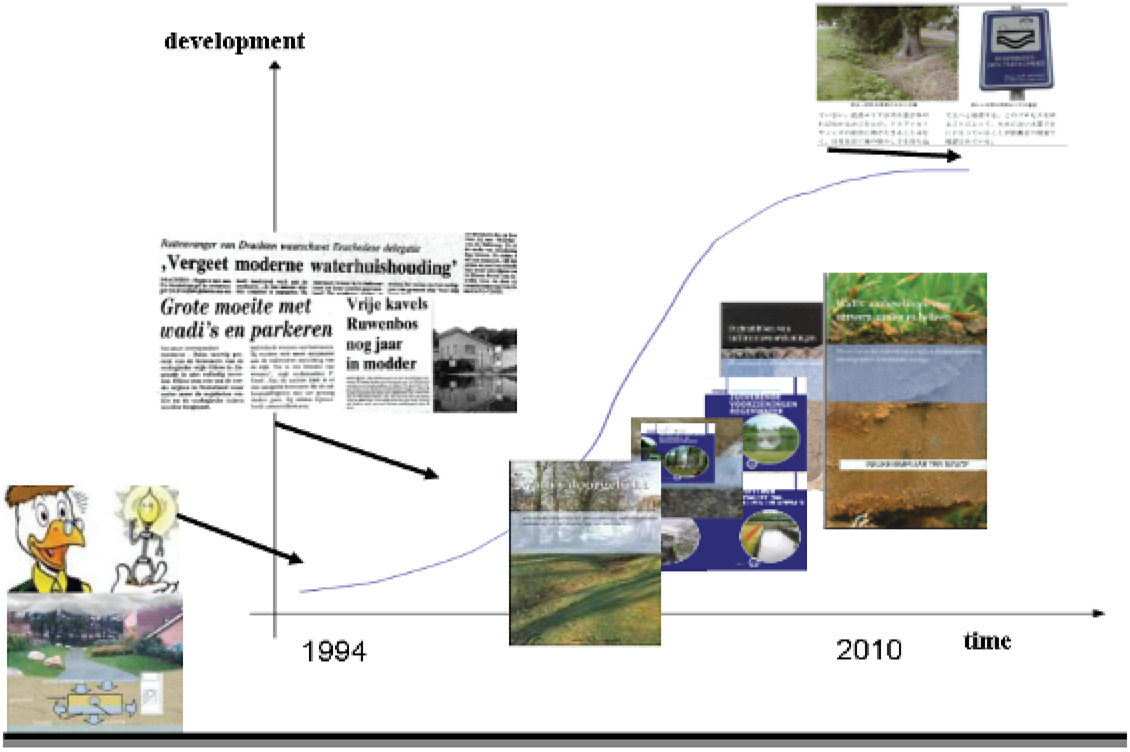


Figure 5 Conceptualization, development, evaluation and implementation of the Wadi system in the Netherlands.

2.1 Conceptualization and implementation of the Wadi in the Netherlands

In 1994, the planning and development of the residential area Ruwenbos in Enschede began. The municipality wanted to create a sustainable district in all aspects, especially in water and greenery. After a study trip to Germany the ‘Mulde Rigole system’ met the need for on site infiltration (on private and public properties), local storage and retention and treatment of storm water.

Soon after, skepticism was raised about this new system in the press: ‘swamps were implemented, rats and malaria mosquitos would take us back to the medieval ages. The sustainability of disconnecting was questioned, as was the quality of rainwater and the effect on receiving waters. More questions about maintenance, cost and required space had to be answered before this alternative to traditional piped drainage could be used. However, German examples showed the benefits of the new approach and the Wadis of Ruwenbos were the first to be constructed in the Netherlands.

At the time of construction, there was little experience with the design and performance of Wadis in Dutch hydraulic situations and this resulted in over-sizing of the elements. Research has been carried out into the infiltration rates and clogging and surveys of resident perceptions. The required maintenance of the system by the municipality have also been carried out. The results have been presented at several conferences and published in papers. This work and fieldtrips carried out by institutions such as municipalities and water boards have resulted in implementation in other housing projects which have also been researched and monitored. The research has resulted in the development of guidelines and by 2010 more over then 2/3 of the Dutch municipalities have the Wadi-system and Ruwenbos was used as an example in many countries such as Japan and the UK, where they have been adopted to control runoff from green space to reduce urban flood risk.

2.2 Implementation of the Wadi system to the UK

The introduction of Wadis into the UK resulted from transnational exchange in during the North Sea Region Interreg IIIB projects NORIS and Urban Water Cycle. The project team members from Bradford City Council recognized the potential of the Mulde Rigole systems in Hannover and the Wadi systems in Enschede and adopted them to control surface water runoff from steeply sloping hillsides which caused flooding in several locations. As well as constructing several Wadis and similar elements derived from them, the project team recognized the need for professionals to see how different types of drainage system could contribute to redevelopment within the city. A knowledge exchange tour was arranged and this has resulted in a significant raising of awareness of the need for integrating land and water management within the city. It also helped to demonstrate the need for projects such as SKINT which provides an environment in which knowledge and experience can be exchange without the need for everyone to visit every site.

2.3 'Educational international SUDS'

SUDS more than traditional piped drainage systems are susceptible to the effects of poor design and workmanship. Examples of well constructed SUDS are quite easy to find, but failing SUDS can be more beneficial in illustrating the consequences of not designing and constructing SUDS properly. Examples of the impact of poor design and workmanship on the performance of SUDS include: reduction of the infiltration or storage capacity, reduction of the discharge capacity and pollution of soil and groundwater.

Figure 6 SUDS: lamella filter (Netherlands), sedimentation basin (Netherlands), swale (Scotland), pervious pavement (Scotland),

Several interviews and international fieldtrips showed that monitoring and performance appraisal are an essential part of the process of commissioning SUDS systems, because these will reveal whether design assumptions are correct and workmanship is satisfactory

Reviewing SUDS from different projects in Europe showed that the uncertainties in design can have a large effect on the performance of the systems. Lack of knowledge about the functions and maintenance of SUDS leads to diminished performance which can result in flooding or pollution of ground and surface water. In this research a lot of effort has been given to find learning aspects of SUDS and translate them in to recommendations to increase the lifespan of these facilities under specific circumstances.

Figure 6 international educational SUDS: sediment load in stormwater basin, insufficient hydraulic capacity of swale, clogging of a infiltration system and bad construction of inflow.

2.4 From Transnational knowledge exchange to guidelines

It can be concluded from the Dutch experience that formal transnational knowledge exchange can play an important role in spreading information about and implementing SUDS around the world. Formal, rather than informal transnational knowledge exchange which can be haphazard is needed to raise the awareness of the functioning of SUDS in different circumstances or countries. The 'educational international SUDS' can be of good use for training the different stakeholders.

Table 2 provides an example of how guidelines for design and construction of swales can be compared. These guidelines are respectively published by:

- Germany (DWA)
- United Kingdom (CIRIA)
- Belgium (VLARIO)
- Netherlands (RIONED)

		Recommended values			
Parameter	**Unit**	**Netherlands**	**Germany**	**United Kingdom**	**Belgium**
Infiltration capacity	m/day	> 0.5	0,86 < Kd < 86,4	-	> 0.086
Distance ground water	m	> 0.5	> 1		
Thickness of filter soil	m	0.3 – 0.5	> 0.1 (average 0.3)		0.3 - 0.5
Area swale to drained area	%	5 – 10	> 7 (average 5 - 20)		5 – 10
Distance to houses	m	> 1	1.5 depth constr. zone		
Overflowing frequency	n/yr	1 to 2	0.2		0.2 - 0.5
Swale water depth	m	< 0.3	< 0.3	< 0.1	< 0.3
Spare capacity	m	0.1		0.15	
Time to empty	hour	< 24	< 24	retentiontime > 10 min.	< 24
Width of bottom	m	> 0.5		0.6	0.5 - 1
Width of water surface	m	4			
Slopes	-	1 : 3 or less		1 : 4 or less	1 : 3 or less
fraction of humus in toplayer	%	3 - 5	2 - 10		
Max velocity	m/s			1 - 2	

The recommended values for the design parameters are more or less in the same order due to knowledge exchange. Some striking differences can be explained by different hydraulic circumstances in the European countries.

3 CONCLUSIONS

Transnational knowledge exchange is needed to raise the awareness of the functioning of SUDS in different circumstances or countries. A good example is the Mulde Rigole system that has been used for many years in Germany and which found its way to the Netherlands around 1997 and was implemented under the name 'Wadi'. Transnational knowledge exchange between UK, the Netherlands and Germany in 2005 has resulted in the first implementation of Wadis in the City of Bradford Metropolitan District and signs of a wider understanding are beginning to be seen.

The monitoring and evaluation of SUDS in different European countries have yielded a wealth of experience which allows us to review and expand our guidelines of SUDS to guarantee their performance in time. The results of research show for example that most municipalities and other organizations pay too little attention to management and maintenance of SUDS. Exchanging knowledge and education will raise awareness and extend the lifespan of SUDS. The 'educational international SUDS' and the guidelines for designing, building and maintaining and monitoring SUDS can be of good use for training the different stakeholders.

Similar databases exist elsewhere and there are potential benefits to be gained by linking the contents of the different databases. The transnational knowledge exchange within SKINT between 2009 and 2011 will contribute to this (http://www.skintwater.eu).

Common failures in the design, construction and maintenance of SUDS are gathered from several international locations and translated to recommendations. Some of these guidelines are:

I. Minimize impermeable areas in the design phase;
II. SUDS should be accessible at all times for maintenance;
III. Proper design and use of SUDS needs adequate communication between the developers, spatial planners, consultants, architects, engineers and inhabitants
IV. sound appreciation of the geo-hydraulic situation is required before designing and constructing SUDS;
V. Properly designed exceedence pathways can reduce the risk of erosion, improve the removal efficiency and minimize the land use in dense populated areas;
VI. Temporary treatment is needed for construction phase-run-off
VII. Filters are required to prevent inflow of course particles into the system
VIII. Detailed documentation of storm water quality measurements and the performance of SUDS can contribute to the enhancements of database and guidebooks
IX. Provide controls to regulate and adjust the system after construction (weir heights etc)
X. Provide a maintenance guidebook
XI. Monitoring (frequently inspecting the system) and sharing knowledge is beneficial to the growth of knowledge and experience

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