REPORT

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International practices and standards of Rainwater Harvesting in urban and peri-urban environment and current R&D projects

Project acronym: WSSTP activities on Alternative Water Resources

by

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for

Kompetenzzentrum Wasser Berlin gGmbH

Preparation of this report was financed in part through funds provided by

Berlin, Germany

2008

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Abstract (English)

Rainwater Harvesting (RWH) is the process of collecting and storing rainwater for a later use. This technique could be an alternative water source in response of a climate change context. In this review, the state of this practice worldwide was studied. Some discrepancies between countries have been highlighted.

First, between developed and developing countries, gaps concerning techniques and regarding the main purposes (water savings for the first ones and drinking purposes for the last ones) were reported. Then, within developed countries themselves, acceptance and standards of RWH installations are different, with precise guidelines and norms for countries leading the way on RWH practices.

The scale of applications (RWH for households – up to 50 inhabitants, for large buildings and for urban area) is discussed and the state of the technique showed that there were more potential of technological development and challenges for large scale systems than for households.

Finally, this report draws the attention to the needs in terms of Research and Development projects. Six main aspects were highlighted: drinking water, energy compensation, environmental impacts, economical aspects and the integration of stormwater management and rainwater harvesting. The last feature concerns hygienic aspect, but the report do not focus on this consideration.

Keywords: rainwater harvesting – state-of-the-art – guidelines and norms – R&D needs – demonstration projects.

Abstract (German)

Die Regenwassernutzung (Rainwater Harvesting, RWH) besteht aus der Regenwasser-Sammlung und Lagerung um es später zu benutzen. Im Rahmen eines Klimawandels könnte diese Technik eine nachhaltige Wasserquelle sein. In diesem Bericht wird eine Literaturstudie über diese Praktik dargestellt. Einigen Disparitäten zwischen Ländern werden festgestellt.

Als erstes werden Untershieden zwischen Industrieländer und Entwicklungsländer über Technik und Hauptzwecke (Wassersparmaßnahme für die ersten und Trinkwasser Anschluss für die anderen) angezeigt. Standard und Akzeptanz von Regenwassernutzungsanlagen sind nicht außerdem gleich drinnen Industrieländer. Richtlinie und Normen sind ebenfalls zur Verfügung in den Industrieländern im Voraus diesem Bereich.

Der Maßstab den Anwendungen wird behandelt (RWH für Haushalt – bis 50 Einwohnern, für wichtiger Gebäude und für Stadtgebiete). Dieser Bericht zeigt, dass wichtiger Gebäude mit großen Flächen mehr Möglichkeiten für RWH (und im Besonderen, technologische Entwicklungen) als Haushalte boten.

Schließlich betont diese Literaturstudie die Anforderungen den Forschungen- und Entwicklungen (R&D) Projekten. Sechs haupt Aspekten werden gefunden: Trinkwasser, Energiesparen, ökologische Konsequenzen, ökonomische Aspekten und die Integration der Regenwasserbewirtschaftung und der Regenwassernutzung. Der letzte Aspekte handelt sich um hygienische Berückschtigungen, aber er war nicht das Hauptziel dieses Berichtes.

Schlagwörter: Regenwassernutzung – Stand der Technik – Richtlinie und Normen – R&D Anforderungen – Demonstrationsprojekten.

Abstract (French)

La réutilisation des eaux de pluie (Rainwater Harvesting, RWH) consiste à collecter et stocker les eaux de pluie pour un usage ultérieur. Ce procédé pourrait être une source alternative en eau en réponse au contexte actuel de changement climatique. Dans cette revue bibliographique, l'état de cette pratique est étudié à travers le monde. Des disparités entre les pays ont été mises en évidence.

Premièrement, des fossés entre les pays développés et les pays en voie de développement ont été rapportés. Ils concernent principalement la technique de réutilisation des eaux de pluie ainsi que ses principaux objectifs (économie d'eau pour les premiers, objectif de potabilisation pour les seconds).

L'acceptation et les standards d'installations de RWH sont par ailleurs très variés à l'intérieur même des pays développés, les pays en avance dans ce domaine possédant des normes et directives précises et ciblées sur cette pratique.

L'échelle d'application est également discutée dans ce rapport (RWH pour un foyer – jusqu'à 50 habitants, pour des constructions plus importantes et pour des surfaces urbanisées). L'état de cette pratique a montré qu'il y avait plus de potentiel de développement technologique et de challenges, pour des constructions importantes mettant en jeu de grandes surfaces que pour de simples foyers.

Finalement, cette revue souligne les besoins en termes de projets en Recherche et Développement. Six aspects ont été mis en lumière: la potabilisation, la compensation d'énergie, les impacts environnementaux, les aspects économiques et l'intégration de la réutilisation des eaux de pluie à la gestion des forts ruissellements. La dernière caractéristique de ces projets en R&D concerne l'aspect hygiénique de la réutilisation des eaux de pluie, mais ce rapport n'avait pas le but de détailler ce point.

Mots-clés : réutilisation des eaux de pluie – état de l'art – directives et normes – besoins en R&D – projets de démonstration.

Acknowledgements

First, I would like to thank Marie-Christine Huau and Dominique Lamure from Veolia Eau for their precious help and for all the information that they gave to me concerning RWH in France.

I express a great thank as well to Tony Rachwall, Research and Development Director for Thames Water whose advices contributed to the knowledge of the state-of-the-art in the United Kingdom.

I thank also all the members of the different associations (UKRHA, IWA) who replied to my e-mails and provided further information concerning the state-of-the-art worldwide.

A special thank to my supervisors – Boris Lesjean, Kai Schroeder and Marco Schmidt - and all the KWB team for their precious help, advices and corrections from the beginning to the end of the working out of this review.

Finally, I would like to thank all persons who contributed to this report.

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Chapter 1

Introduction

Rainwater Harvesting (RWH) can be defined as the process of collecting and storing rainwater for a later use, such for toilet flushing, washing machine, garden watering, irrigation, cleaning purposes, process water, fire fighting, car washing, cooling water and drinking water. This practice has been used for a long time. Its traces have been found from biblical times such as in Palestine and Greece, some 4.000 years ago, where it was used in semi-arid and arid regions. At that time, the main purpose of RWH was to supply water in case of a drought.

Nowadays, RWH is increasing worldwide, with various aims, techniques and problematic – backgrounds in other words – according to the location of these RWH systems. Two main backgrounds for these RWH systems could be however highlighted.

The first one concerns most of developed countries which have to cope with pollution and flooding problems due to limitations of the centralized (end-of-pipe) character of the wastewater systems. Indeed, in case of strong runoffs, the sewage networks and the urban sewage plants can be overloaded, thus generating a potential threat for environment. That is one of the reasons why RWH can be used (among other solutions such as green roofs) as a mean of reduction and retention of peak runoff.

The second one involves developing countries, where RWH can be considered as an alternative source of water supply for regions lacking of real water networks and suffering from an unfavourable water situation.

Furthermore, the present climatic background and the global demography increase in most countries should not be forgotten. This environmental and demographic context is the reason for countries to find out new alternative water sources such as RWH.

The second chapter of this report deals with the state of the practice of RWH worldwide, then in a third part current design guidelines and standards are identified and technical aspects of RWH systems are presented. Interesting and particular projects worldwide are selected and presented in Chapter 4. Finally, current R&D projects, knowledge gaps, and needs as well are discussed in Chapter 5. Appendixes provide further information on current and past R&D projects worldwide, firms, contacts and associations dealing with RWH.

Chapter 2

State of Rainwater Harvesting worldwide

2.1 Germany

Germany is not currently facing up significant water scarcity issues, consequently, there seems to be no reasons at first sight to implement RWH systems in this country. However, to cope with the limitations and adverse effects of conventional stormwater collection (in combined as well as in separate sewer systems) there is an increasing application of decentralized stormwater management concepts for 20 years. In regions with low water availability, these concepts have been combined with RWH solutions. It began in Hamburg with the first supporting program for Rainwater use in buildings in 1988. Currently, 15% of German municipalities support private projects of RWH for 50% [*Perraud, 2005, (1)*]. In addition of tax incentives, the environmental friendly aspect and the (supposed) return on investment of RWH systems enhance the German to implement these systems.

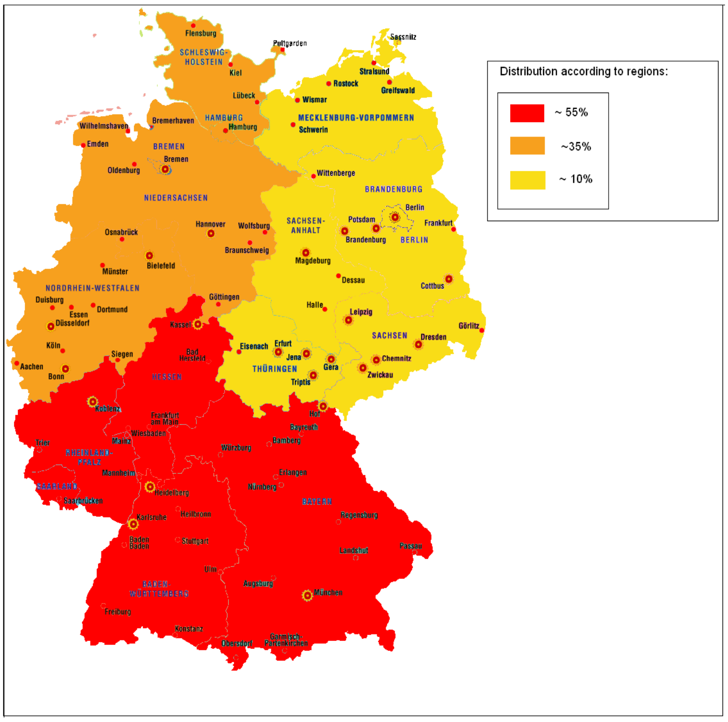

Figure 1 Distribution of implemented RWH systems in Germany according to regions.

According to a market survey carried out by the manufacturer Mall GmbH in 2006, 1,6 Million rainwater use systems were set up in Germany, with an increase of 75.000 to 85.000 tanks per year. 50% of these new tanks are made of concrete, the others of plastic, and 70% are located in new buildings. In a report published by the Senate Department for Urban Development of Berlin [*Innovative Wasserkonzepte, Senatsverwaltung für Stadtentwicklung, 2003, (2)*], 15 significant projects in large buildings are listed concerning Berlin, but there might be over 100 large buildings in Berlin.

This market represents 400 Million Euros of sales and 5.000 employments. The distribution of these appliances is represented by figure 1.

As a matter of fact, the contribution of the Fachvereinigung Betriebs- und Regenwassernutzung e.V.[1] – fbr – the normalisation investigation from the Deutsches Institut für Normung e.V. – DIN – and the many investigated projects regarding RWH help Germany to be worldwide leader in this sector.

Rainwater use enables to save water thanks to its application in households. The average demand of water in a household amounts to around 127 L per person and per day. The use of Rainwater for washing machines, toilet flushing and garden watering would be able to save around 45% of the total demand of water in a household, as shown on figures 2 and 3.

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[1] The German professional association for process and rainwater reuse

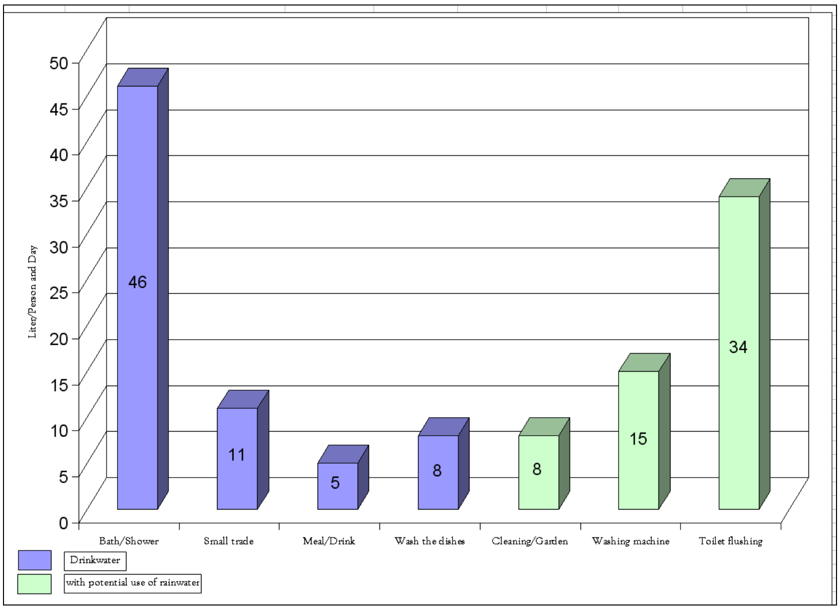


Figure 2 Use of water in households and small businesses per person and per day *[UmweltBundesAmt, 2004, (3)]*

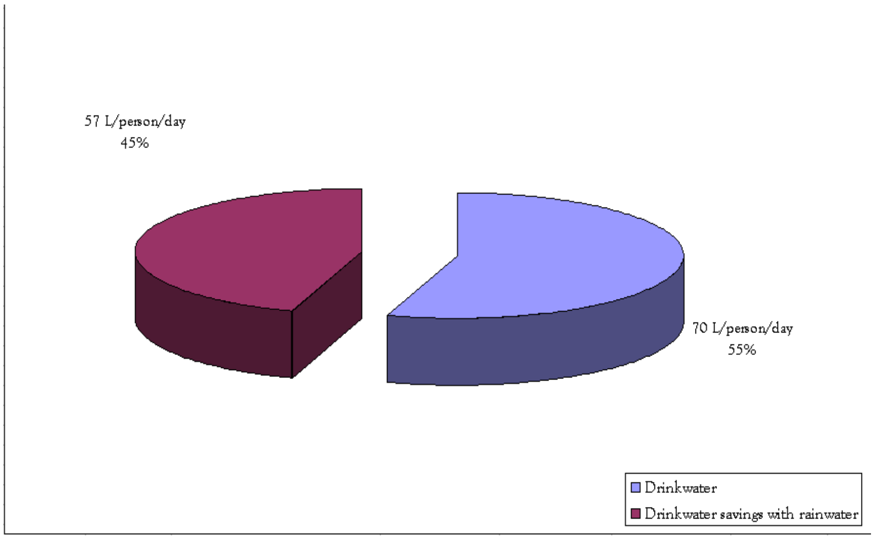


Figure 3 Percentage of water-savings with rainwater *[UmweltBundesAmt, 2004, (3)]*

2.2 Europe

2.2.1 Overview

Thanks to the EU Water Framework Directive (2000) implemented to protect the aquatic environment; some requirements have been set up involving the potential use of Rainwater Harvesting.

Some of these requirements can be quoted:

* prevent further deterioration, protect and enhance the status of aquatic ecosystems, with regards to their water needs, terrestrial ecosystems and wetlands (Article 1 (a)).

* promote the sustainable use of water based on long-term protection of available water resources (Article 1 (b)).

The contribution of Rainwater Harvesting would enable to:

* reduce reliance on centralised water treatment and distribution system that appropriate water from the natural environment.

* decrease the instances of urban flooding by reducing both the volumes of water disposed to the sewer systems and the peak flow rates within sewers.

* provide a water supply “buffer” in case of a drought.

However, every European country has adopted a different perspective concerning the use of rainwater because of its own interpretation of the word “domestic” used in the European directive 98/83/CE (3/11/1998). Consequently, some of them – such as France – do not use rainwater for domestic uses; whereas others use it for toilet flushing and washing machine and few of them, such as the Netherlands, simply forbid it since many contamination case of water network have been reported.

Some European countries are following the way of Germany. Rainwater Harvesting is a widespread practice in Sweden, Norway, Luxembourg, and Belgium. In Belgium, for instance, national legislative procedures made it compulsory for new buildings to have Rainwater Harvesting systems in order to supply toilet flushing and outdoor uses.

No other information concerning RWH in the Scandinavian countries and on the South and East-European countries have been found.

It should be stressed that the state of this practice, in developed countries, depends on the water price. The higher the price, the better the amortisation of the plant is [*König, (4)*]. For instance, Denmark (1,84€/m³) and Germany (1,73€/m³) have high cost and are strongly active in this field. In terms of cost, the fbr estimated (2008) that the cost of a device for a household was around 3.000 – 4.000€ and that a paying off of 10 - 20 years could be expected.

It seems that European regulations present a lack in this field and because of the different interpretations that countries may have about the already existing ones, there is no consensus or common practice inside Europe. Moreover, the few return on experiences regarding sanitary issues do not encourage some countries to develop RWH.

2.2.2 France

France has got a favourable water resources context, with around 500 billion m³ of rainfall per year, among which 200 billion m³ per year are efficient and 2.000 billion m³ are Groundwater. In spite of this, France has already encountered water troubles such as low precipitation and sinking Groundwater. In response to these problems, some decreed restrictions have been implemented in the concerned regions during summer such as the prohibition of car wash, prohibition of irrigation etc. Besides, the Rainwater resource is not well distributed and the regions with strong consumption do not match with areas which have a strong potential of rainfall [*Office International de l'Eau, 2008, (5)*].

New measures have been taken with the “Plan de gestion de la rareté de l'eau” (26/10/2005) which stands for “Planning of water scarcity management”, including a better water promotion, with among other things, the promotion of water infiltration and Rainwater Harvesting.

At first sight it seems that Rainwater Harvesting is going to have a great implementation in France, but in fact, this practice copes with regulations and health difficulties and particularly when it implies domestic uses. Presently, only external uses (garden watering, cleaning…) are therefore admitted, except in particular cases (lack of water, no public water network). However, the increasing demand from private customers and the new “Haute Qualité Environnementale” method encourage authorities to reconsider Rainwater Harvesting. As a result, a new decree should soon authorize and precise rainwater use inside the buildings and would supplement the tax incentive for households concerning outdoor use (August 2007).

Despite reluctance from sanitary authorities, there are already devices using Rainwater Harvesting. According to providers, 10.000 systems have been implemented, among which 67 concern large buildings. The distribution of the kind of architectural projects and the different uses listed are shown on the figure below.

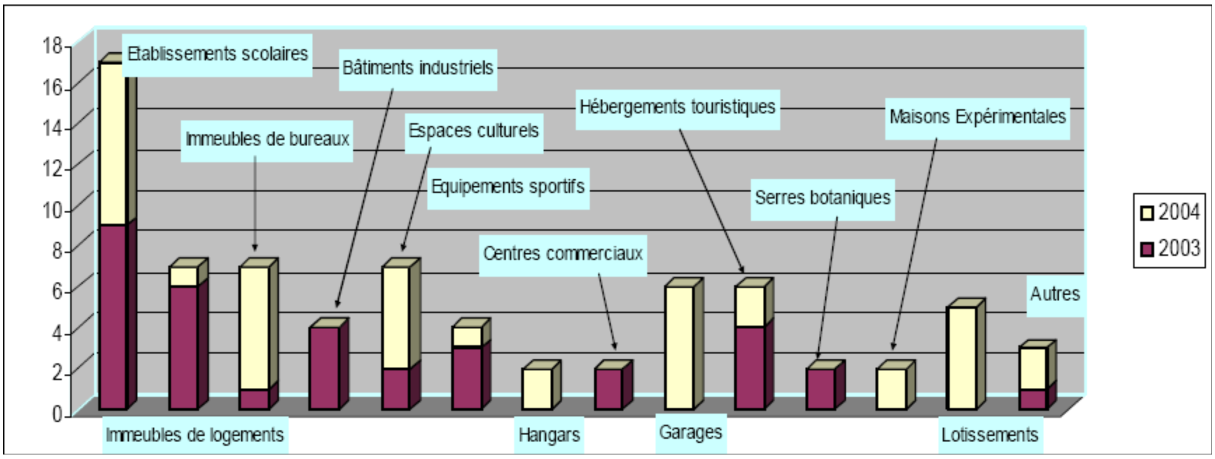


Figure 4 Repartition of French projects in large buildings. [Guide CSTB Arene, (6)]

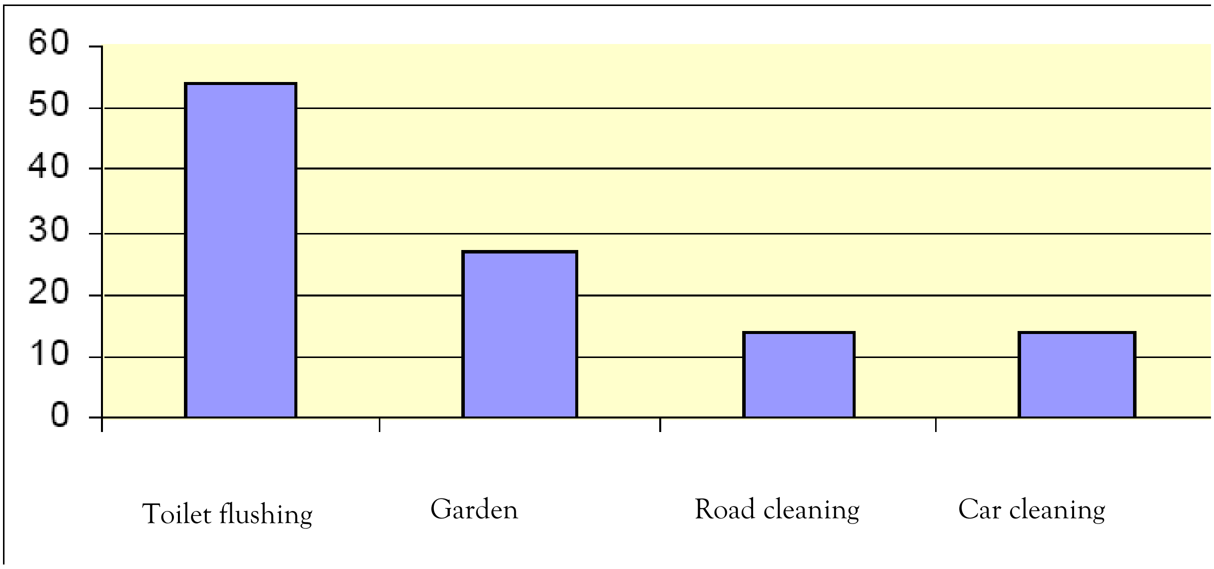


Figure 5 Distribution of the different applications in France [Guide CSTB Arene, (6)]

It is clear that the main use of Rainwater is dedicated to toilet flushing (around 76% of the whole use) and it is particularly used in schools and service buildings as well.

2.2.3 The United Kingdom

Even if United Kingdom receives on average 900 mm of rainfall per year, which is above the global average of 750 mm/year, this rainfall is not evenly distributed, which has caused water scarcity troubles in some regions. Unfortunately, the regions that are lacking of water are those that have also a high population density, such as London and the surrounding south-east of England. The combination of a weak rainfall rate with a high population density has generated water stressed regions (regions with less than 1000m^3/person/year of freshwater). On top of that, many of these regions are now reaching the maximal capacity of their natural catchments' water resources [*Rachwal, 2008, (7)*] making thus water situation worse.

As a consequence, a new water management is now considered: encouraging water saving behaviours (for instance: use of water saving taps, new building regulations…), metering existing domestic households and variable demand tariffs, using alternative water resources such as greywater or rainwater, etc.

The market of Rainwater Harvesting is hence gradually developing and encouraged by the United Kingdom Rainwater Harvesting Association (UKRHA), founded in 2004. Thanks to a market survey carried out by the UKRHA and the companies which belong to the association, we can observe that the number of domestic systems sold increases dramatically within a period of 5 years (from 2003-08-31 to 2008-05-31). On the other hand, the number of commercial systems increases as well, but more steadily than in the case of domestic systems.

In May 2008, a total of 4356 commercial and 15 088 domestic systems have been sold since 2003.

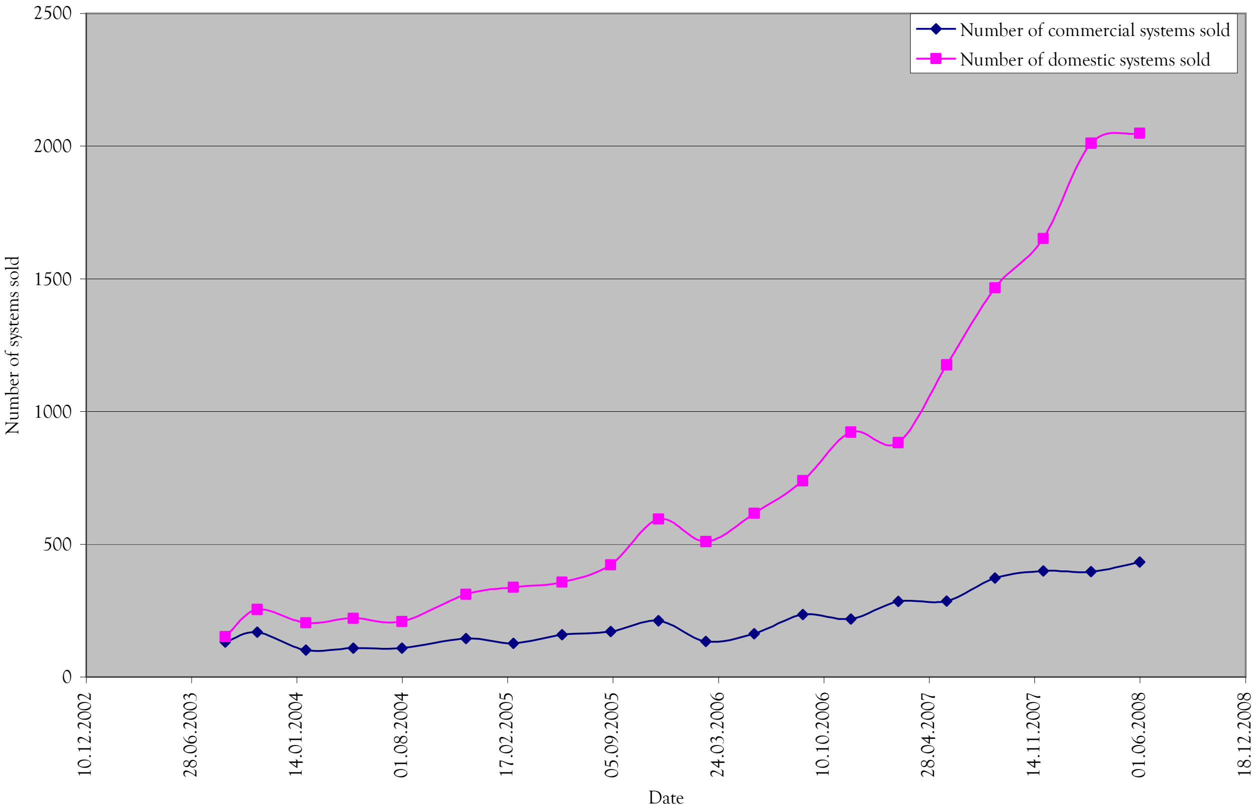


Figure 6 Evolution of the RWH systems sold in UK [UKRHA, 2008]

One of the most used practices of RWH in the UK is the reuse of rainwater for garden watering. This is due to the simple and low cost of this kind of installation for a household level. However, the conventional rainwater tank volume of only 100 - 250 L is not adapted to fully exploit the potential rainfall of urban areas. In contrast, Australian standards recommend the use of a 3-5 m^3 rainwater tank per household.

RWH for toilet flushing, in spite of the fact that it is a worldwide practice, is technically feasible but not widespread in the UK, where only a few examples are reported. RWH in the UK may therefore need to reassess the scale of the storage devices to be more efficient and to find other fields of application.

2.3 World

2.3.1 Africa

There is an expansion of Rainwater catchment systems in some parts of Africa, but slower than in Southeast Asia. Lower rainfall, seasonal nature of rainfall, smaller number and size of impervious roofs, higher costs of constructing catchment systems can explain this slow expansion.

However, Rainwater is spreading and Kenya is leading that way. Many projects have been carried out since the 1970s with their own design and implementation strategies and about 10 000 Rainwater tanks were set up [*Han, 2004, (8)*]. On top of that, some projects are being investigated with European countries support: the EU-project Zer0-M for Egypt, Tunisia and Morocco is an example.

Rainwater Harvesting practice gives the opportunity for a family to live for a year in areas with a rainfall of 100 mm/year [*Saleh, 2004, (9)*]. Observations made in Zimbabwe and Botswana have shown that 80 to 85% of all measurable rain can be collected and stored from catchment areas (1996)

2.3.2 Americas

2.3.2.1 Brazil

Due to climatic problems – rainfalls are located above the big cities and do not fill the water reservoir in the highlands - the Government agencies implemented the construction of RWH systems for roof surfaces above 500 m². In the North of the country, a program of one million cisterns should provide a basic water supply [*König, (4)*].

2.3.2.2 North America

In the USA, RWH is especially used in states where there are strong water shortages such as Maine, California, Oregon, Texas (notably for irrigation) and Washington [*König, (4)*]. The American Rainwater Catchment Systems Association ARCSA and the new building rating systems (such as LEED™ Leadership in Energy and Environmental Design) encourage the development of RWH in order to counterbalance the lack of RWH technologies and environmental awareness.

But some efforts deserve to be noted: according to the president of ARCSA, one-half million people are using Rainwater for indoor and outdoor purposes for mainly toilet flushing and irrigation and a few of them for potable purpose.

In spite of the cost of potable water which is not a driver compared to cost for conveying and treating storm and sewer flows [*Moddemeyer, 2004, (10)*], RWH has found some applications on an industrial scale as represented on the table below [*Moddemeyer, 2004, (10)*]:

		Irrigation (or other)	Toilet flushing	Potable
Albuquerque, New Mexico	City of Albuquerque Rainwater barrel rebate	X		
Austin, Texas	Samsung Electronics	X		
	AMD (Advanced Micro Devices)	X		
	Motorola Corporation	X		
	Elementary school	X		
	Homeless shelter	X	X	
	Veterinary clinic	X		
	National Wildflower Research Center	X		
Bainbridge Island, Washington	Island Wood Environmental Education Center	X	X	
Detroit, Michigan	Ford Motors River Rouge plant	X		
Madison, Wisconsin	University of Wisconsin at Madison			
Milwaukee, Wisconsin	Urban Ecology Center	X	X	
Portland, Oregon	Dr. Ole Errson (residential)	X	X	X
	Station Place elderly housing – 170 units		X	
	Epler Hall, Portland State University	X	X	
	Block 25, Oregon Health Sciences University	(used for cooling; ground-water reclamation)	X	
Phoenix, Arizona	Airport car rental lot	X	X	
San Antonio, Texas	City of San Antonio	(using condensate from cooling for irrigation)		
San Juan Islands, Washington	Residential use (numerous)	X	X	X
Santa Fe, New Mexico	Rancho Veijo		X	
Seattle, Washington	Seattle City Hall	X	X	
	Seattle Public Library	X		
	King County Department of Natural Resources Building	X	X	
	Residential use (numerous)	X	X	
	La Farge	(used in industrial processes)		

Table 1 American industrial sites with a RWH system.

In Canada, the practice of RWH is hindered due to the fact that roofs are made in wood which is often treated with fungicides, thus influencing the water quality. On the opposite, in the coastal regions of the Atlantic and the Pacific(except in Canada), where roofs are made of wood and treated as well as in Canada, rainwater is used commonly as a potable water supply although there could be sanitary risks [*König, (4)]*

2.3.3 Asia

2.3.3.1 China

China has to cope with a serious scarcity of water in some regions due to both spatially and temporally uneven water distributions. Since the 1980s, research, demonstrations and extension projects in Gansu (one of the driest provinces) have been carried out and Rainwater has been used as an irreplaceable measure for human survival and development.

The project in Gansu began in 1988 and its main purposes were to study rainfall-runoff relationship (or Rainwater Collection Efficiency RCE) to find out the appropriate Rainwater use pattern and to formulate the design procedure for the Rainwater harvesting system. The first reuse of Rainwater was a domestic use and it has been then extended to production.

As a consequence of the serious drought of year 1995, the “1-2-1” Rainwater Catchment Project was implemented and should solve water shortage where no surface and groundwater exists but where only Rainwater is available. Decisions taken for each family are follows:

* Build one treated catchment with an area of 80 to 100 m².
* Build two underground water tanks with a volume of 15 to 20 m³ each.
* Build one piece of land close to the household to be irrigated with stored rain.

These requirements were met in 1996 for **1,31 million people in 264.000 families, in 2.018 villages, under the jurisdiction of 27 counties** [*Qiang, 2004, (11)*]. As a result, this success has generated other “Rainwater management” behaviours: people in these households have updated their roofs, paved the courtyard with concrete slabs to collect Rainwater (it now concerns around 37,16 million m²) and 286.000 newly designed water cellars are being built.

A new project was initiated in 1996 as well: Rain Water Harvesting Irrigation Project in order to develop the economy and improve the life conditions of farmers. That is how, in order to low the costs, Rainwater has been collected from all kind of surfaces: paved highway, country road, threshing yard and natural slope. Then the collected water is only applied in the critical periods for crop growth with a quota of 150-300 m³/ha and systems like drip and mini-spraying are implemented.

At the end of 2001, 2,2 million storage tanks were built which allowed an extra irrigation on 236.000 ha of land. The project is still developing with a speed of enlarging 33.000 ha of irrigated land each year.

Other projects have been implemented since 2000 and RWH in China is becoming more and more widespread.

2.3.3.2 South Korea

Rainwater in Korea has always been considered with high interest since it was traditionally a task for the highest authority, that is to say the King.

Currently, Rainwater is getting an increasing interest and the development of policies helps to its implementation. In 2003, "a special law concerning the promotion of Rainwater outflow reduction and institutional installations for storm, flood damage and drought mitigation" is set up [*Han, 2006, (12)*]. For instance, a stadium with a roof surface area larger than 2.400 m^2 or with more than 1.400 seats now has to store and use Rainwater [*Dockko, 2006, (13)*].

Besides, some projects are investigated to promote Rainwater Harvesting Use System. For example, a Rainwater reuse system that consisted of a pre-filter, a membrane and a disinfection system was developed so that the treated water meets Korean standard and guidelines requirements, and to extend its use for recreation, toilet flushing, cleaning and gardening of Rainwater, including non point pollutants in urban parking area.

The most frequent Rainwater uses we can find as well are the following: decreasing the temperature by spraying roofs with stored Rainwater (after cooling, water is recycled and reused), small Rainwater tanks are used to extinguish fires…

Finally, some experimental projects (see Chapter 5, section 5.3.) are realised, thus making Korea one of the most progressive countries worldwide regarding Rainwater Harvesting.

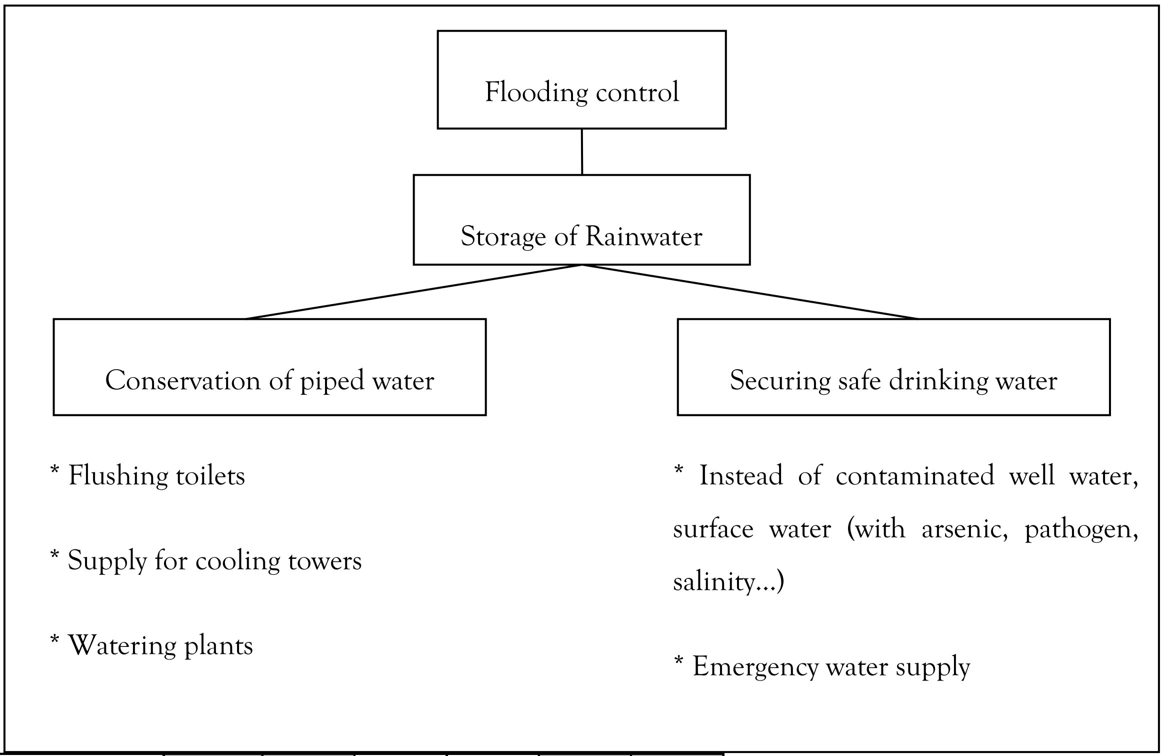
2.3.3.3 Japan

Japan is one of the Asian developed countries that are leading the way of RWH thanks to, among other things, its Council of Rainwater Utilization for local governments established in 1995 by Sumida City and the Rainwater Museum of Sumida.

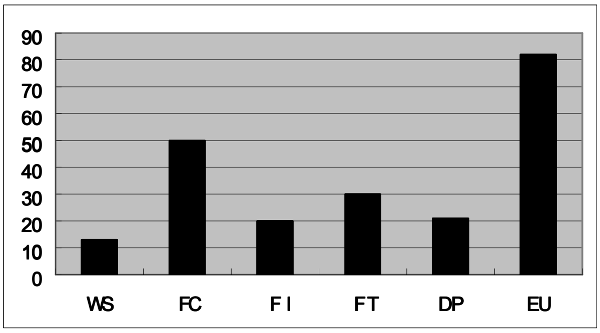
Presently, there are around 3.400 buildings equipped with Rainwater Harvesting Use System at private and public levels in the Japanese big cities such as Takamatsu, Fujisawa, Kawaguchi [*Murase, 2004, (14)*] This figure can be explained by the "Rainwater Utilization

Promotion Guidelines" (1995), which, first, implement the set-up of Rainwater use systems in the new facilities, then encourage the developers to use Rainwater harvesting system over a fixed scale development of 500 m² and last, take into account the support of Rainwater tank facilities for citizens.

The utilization and the objectives of Rainwater in Japan can be divided as follows:



Objectives	WS	FC	F I	FT	DP	EU
Number of Answers	13	50	20	30	21	82



WS: Water Shortage Mitigation

FC: Flooding Cotrol
FI: Infiltaration
FT: Tank Storage

DP: Disater Prevention

EU: Effectie Use of Water

Answers: 141 Local Governments of Japan
By Council of Rainwater Utilization for Local Governments

(July- December, 2002)

Fig.2 Objectives of rainwater harvesting and utilization

Figure 7 The Utilization and Objectives of rainwater in Japan. [Murase, 2004, (14)]

It should be noted that Japan, due to its geographical location, regularly faces earthquake events. Rainwater utilization can therefore be a water supply option in case of natural disasters.

2.3.3.4 Indian peninsula

2.3.3.4.1 India

Like China, India presents an uneven water situation: in the North- West Himalayan region of India, the annual rainfall is 1.750 mm high on average, with 71% received during the tropical monsoon period (July and August) and 79% going as runoff and stream flow [*Sharma, 2004*]. RWH is a common traditional practice contributing to 10% of the water availability for agriculture and 40% for the population use which can be coupled with runoff management to be more efficient.

2.3.3.4.2 Pakistan

Since more than 70% of the surface area is arid or semi-arid and that the natural fresh water resources are limited in Pakistan, it appears that RWH could be a water supply option. That is the reason why the Pakistan Council of Research in Water (PCRWR) has undertaken RWH project in Cholistan Desert. Currently, 50.000 m^3 of Rainwater is used for drinking and other purposes. [*Amin, 2006, (15)*]

2.3.3.4.3 Bangladesh

The climatic conditions in Bangladesh are similar to those in India, and RWH remains a traditional practice in this country. Over one third of the people in coastal and hilly areas are using Rainwater for drinking, cooking and other domestic purposes. The potential healthy risk caused by the presence of Arsenic in groundwater encourages the use of Rainwater as well. However, since 80% of the Bangladeshi population live below to the poverty line, they can not afford important RWH installations. Japan – with the People for Rainwater NGO - has therefore helped to develop low cost systems with the Bamboo Kits which have encountered a great success. In spite of the poverty, technological innovations have been carried out in order to set up different rainwater collection systems. For instance, a concrete or metal Rainwater collection system with a 2-3 m^3 volume capacity should be able to supply a household of 5-7 members, 5-8 families with a capacity of 15-25 m^3, and at last 100-300 families with a capacity of 100-200 m^3.

2.3.3.5 Thaïland

RWH in Thailand remains a popular practice using simple systems. The Royal Thai Government Rural Water Resources Policy introduced in 1979 three small scale technologies: jars/tanks for drinking water, shallow wells for domestic water and small weirs for agriculture. Since 1987, RWH practice has increased gradually as shown by the following chronology [*Vigneswaran, 2006, (16)*]:

* 1987: 24% of the rural population is served by Rainwater Harvesting

* 1990: this rural population increases of 35% [WHO/UNICEF, 2004]

* 1992: eight million of 2 m^3 rain jars are in use

* 2005: Rainwater jars remain popular.

2.3.3.6 Sri Lanka

Traditionally, Rainwater is collected for a domestic use from tree trunks, using banana or coconut leafs or from rooftops into barrels, domestic containers and small brick tanks.

Since 1995, a lot of projects and organizations have been implemented in Sri Lanka and the LRWHF – Lanka Rain Water Harvesting Forum – is able, thanks to a database, to quantify the units all over Sri Lanka: 22.543 were listed all over the country.

The main uses of this Rainwater are: home gardens, drip irrigation, mushroom cultivation, poultry and goat rearing, running a boutique, toilet flushing, washing purposes and so on.

It has been estimated that RWH could save 30% of the time of beneficiary households (no need to fetch water anymore) [*Ariyananda, 2004, (17)*].

2.3.3.7 Singapore

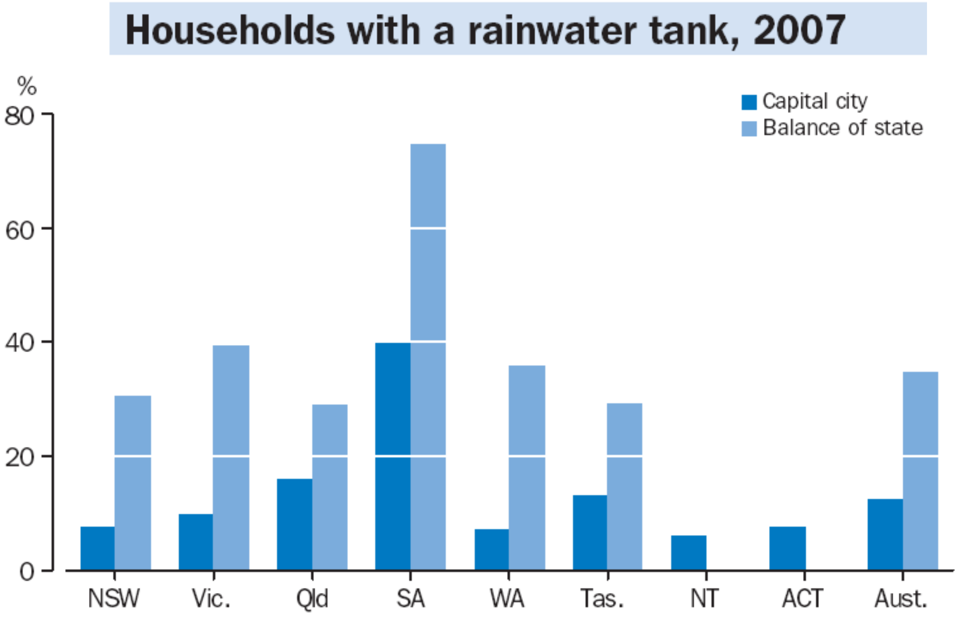
Singapore came up with the idea of Rainwater Harvesting quickly with the Bedok – Seletar scheme which is one of the world's first urban water harvesting projects in late 1970s. This project was a drainage system able to collect runoff from around 5 000 ha of the surrounding urbanised catchments thanks to the construction of 9 stormwater collection stations.

Currently, 48% of the land area of Singapore is being utilized as water catchment [Appan and Seng, 2001] and around 50% of roofs are equipped with RWH systems [*Bouteleux, 2007, (18)*]. This can be explained by the increasing population and consequently the water demand.

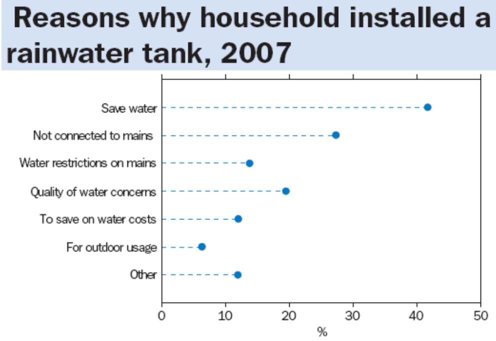
Other innovative projects are carrying out, such as in Temasek Polytechnic (see Appendix A).

2.3.3.8 Australia

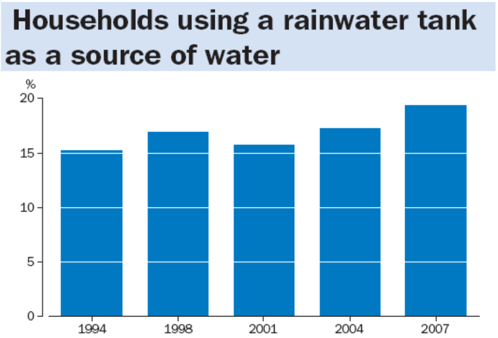
Since private households consume an important part of the total drinking water requirement (70% in Sydney), the Government of New South Wales has undertaken measures in order to reduce water consumption. For instance, a programme was set up in 2005, which consists in evaluating the sustainability of buildings (Building Sustainability Index, BASIX) and as a consequence in promoting Rainwater system installations. According to the Australian Bureau of Statistics (ABS), more than one fifth (20,6%) of all the households reported that their dwelling had a Rainwater tank, and up to 80% in the rural area of the South-Australian State.


Households with a rainwater tank, 2007

Note: NT and ACT data refers to the whole territory.
Source: ABS, Environmental Issues: People's Views and Practices, 2007 (cat. no. 4602.0).


Reasons why household installed a rainwater tank, 2007

Source: ABS, Environmental Issues: People's Views and Practices, 2007 (cat. no. 4602.0).


Households using a rainwater tank as a source of water

Source: ABS, Environmental Issues: People's Views and Practices, 2007 (cat. no. 4602.0).

Figure 8 State of RWH applications in Australian households

Mostly, Rainwater harvesting systems are used for domestic purposes (toilet flushing, garden watering…). Nevertheless, since State Government Health Departments do not prohibit the use of Rainwater for drinking or other purposes, it has been estimated that over 3 Million Australians used Rainwater from tanks for drinking [*ABS, 1994*] in urban and rural regions with no reported epidemics or widespread adverse health effects. However, the hygienic quality of Rainwater stored generates strong debates within the scientific community.

On top of using common tanks to have an additional source of water, Australia is evolving into a comprehensive and innovative water management, namely Water Sensitive Urban Design (WSUD), based on a concept called "The City as a Catchment". This concept involves a comprehensive overview of the urban water and the interactions between the natural environment and the built environment.

Australia is therefore one of the countries with most advanced conception of its urban water system.

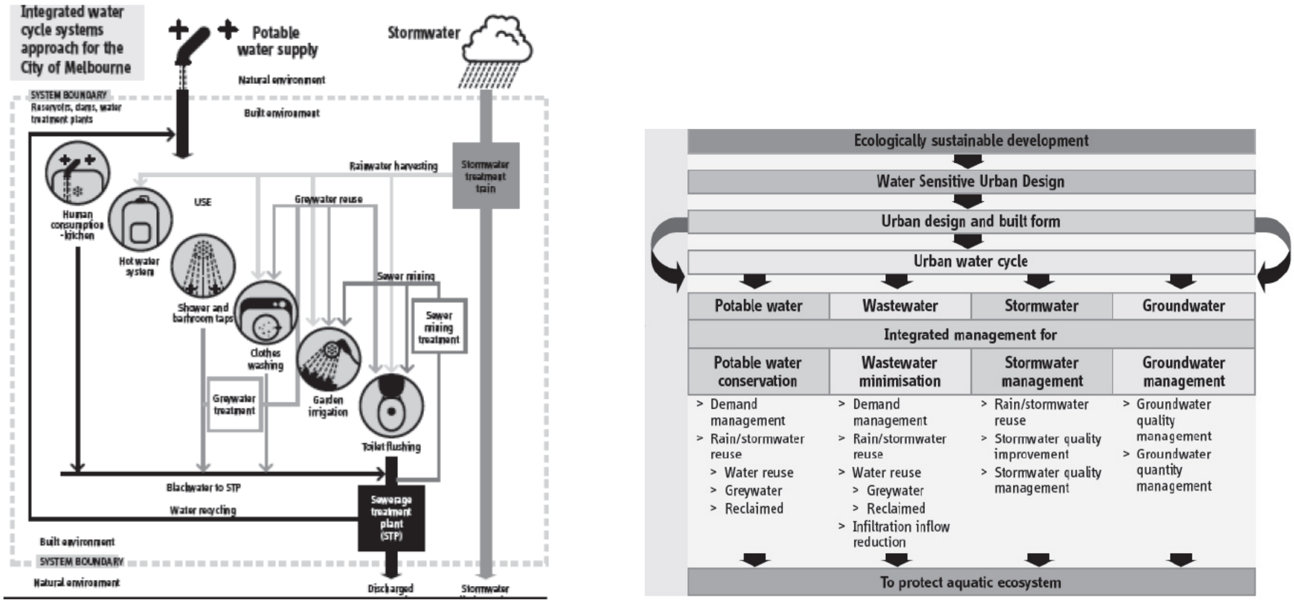


Figure 1: **The flow of water from the perspective of the user**
(WSUD Guidelines 2005)

Figure 2: **Water supply flows**
(WSUD Guidelines 2005)

Figure 9 Integrated water management in Australia

Chapter 3

Design guidelines and standards in Europe

3.1 Technical considerations

3.1.1 General aspects

In spite of the various possibilities that offer the use of RWH, this technique can be described according to a fundamental process [*Roebuck, (19)*]:

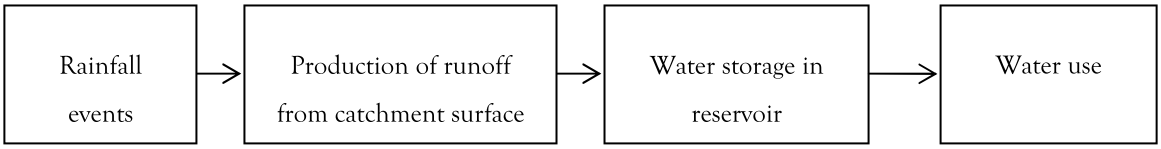
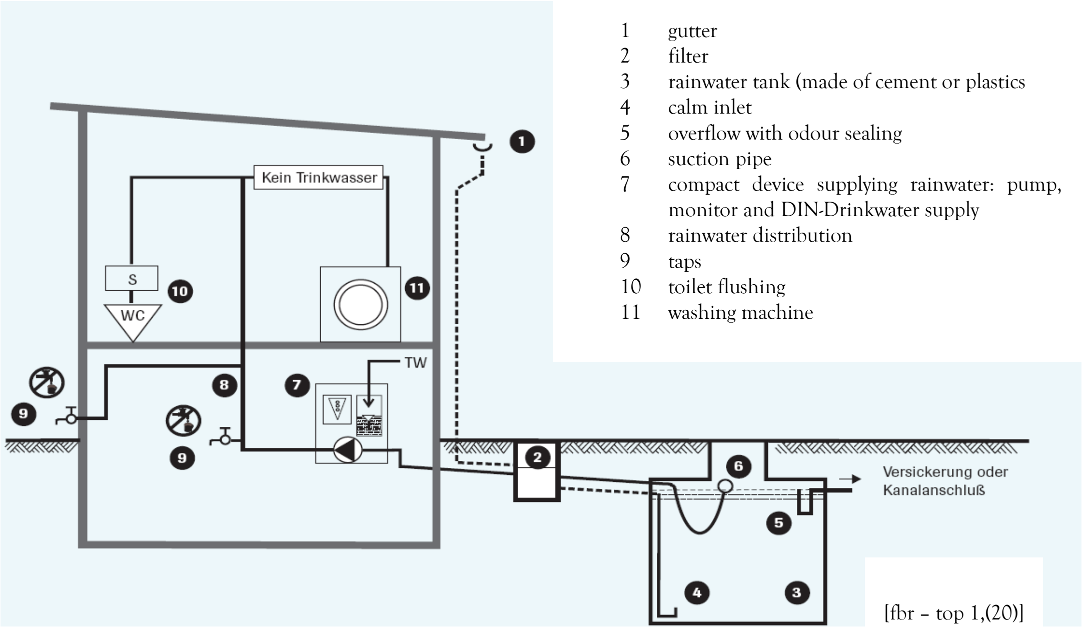


Figure 10 Fundamental process of RWH

The key components in a household that modern systems comprise of are as follows:



[fbr – top 1,(20)]

Figure 11 Scheme of a current RWH device in a household

Rainwater is first collected from roof surface and filtered before entering a tank by a quiet inlet, thus enabling sedimentation. Then the water is lead by a suction pipe and by pumps inside the household. The potential overflow is either infiltrated, or lead in the canal.

Some devices can also introduce the use of first-flush diverters before the first filter. The goal of such apparatus is to retain the first flush, which is oft the most polluted. Indeed, this first-flush wash away most of the contaminants which built up on the catchment surfaces during long dry periods.

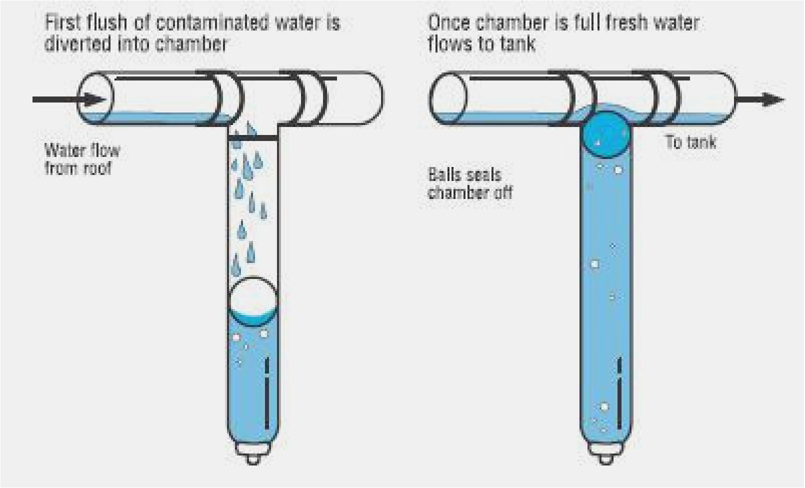


Figure 12 Operating of a first flush diverter [www.rainharvesting.com.au]

The amount of water diverted should be a minimum of 20 litres per 100 square metres of roof area (or 0.2L per m^2). A slow release valve ensures the chamber empties itself after rain and resets automatically. [www.rainharvesting.com.au]

3.1.2 Combination of a RWH system with green roofs catchment areas.

A combination of a RWH system with a green roof can be also considered. The green roof will have three main consequences on the building. The first consists in pre-filtering rainwater before being lead in the tank.

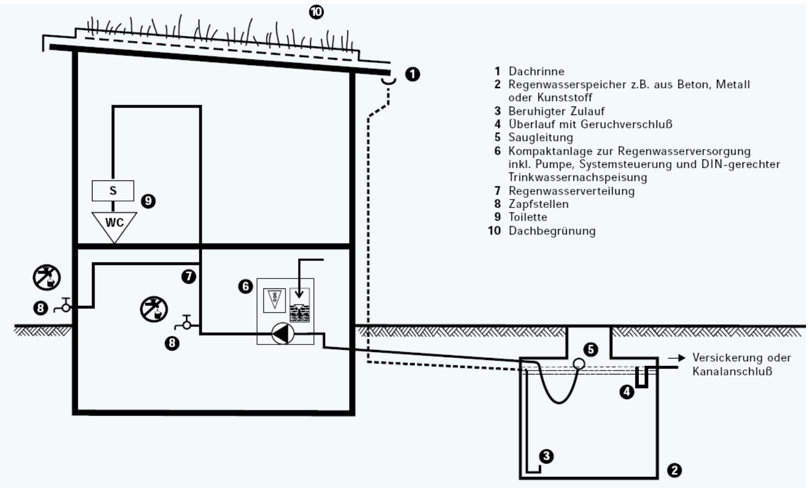


Figure 13 Scheme of a combination of a RWH device with a green roof [fbr-(20)]

Then, the presence of green roofs fulfils a stormwater retention function. According to a study carried out by the Lady Bird Johnson Wildflower Centre at the University of Texas in Austin, this retention ability of green roofs appeared to be the most variable feature of the different roofs which were studied. The retention depends indeed of the importance of the rainfall and of the composition of the roof: the better roofs are able to retain all of the water during a 12 mm rainfall episode and under half of the water during a 50 mm event. But some roofs retains just 25 % of the 12 mm event and as little as 8 % during the heavier rainfall.

What is retained by green roof is not available for water recovery: it disappears in evapo-transpiration thus providing a cooling effect to a building's interior. But this last aspect is minimal when compared with the both previous.

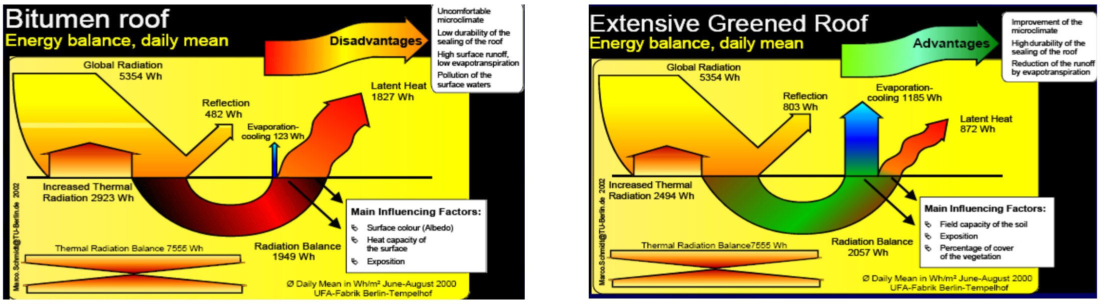


Figure 14 Energy balance comparison between a bitumen roof and a green roof

3.1.3 Combination of a RWH system with an infiltration device – Possibilities.

This kind of installation enables particularly to manage the overflow within the rainwater reservoir, thus avoiding charging the canal which normally has to deal with this overflow. Many types of facilities may be set up. Figure 15 represents three of them [*fbr, (20)*]:

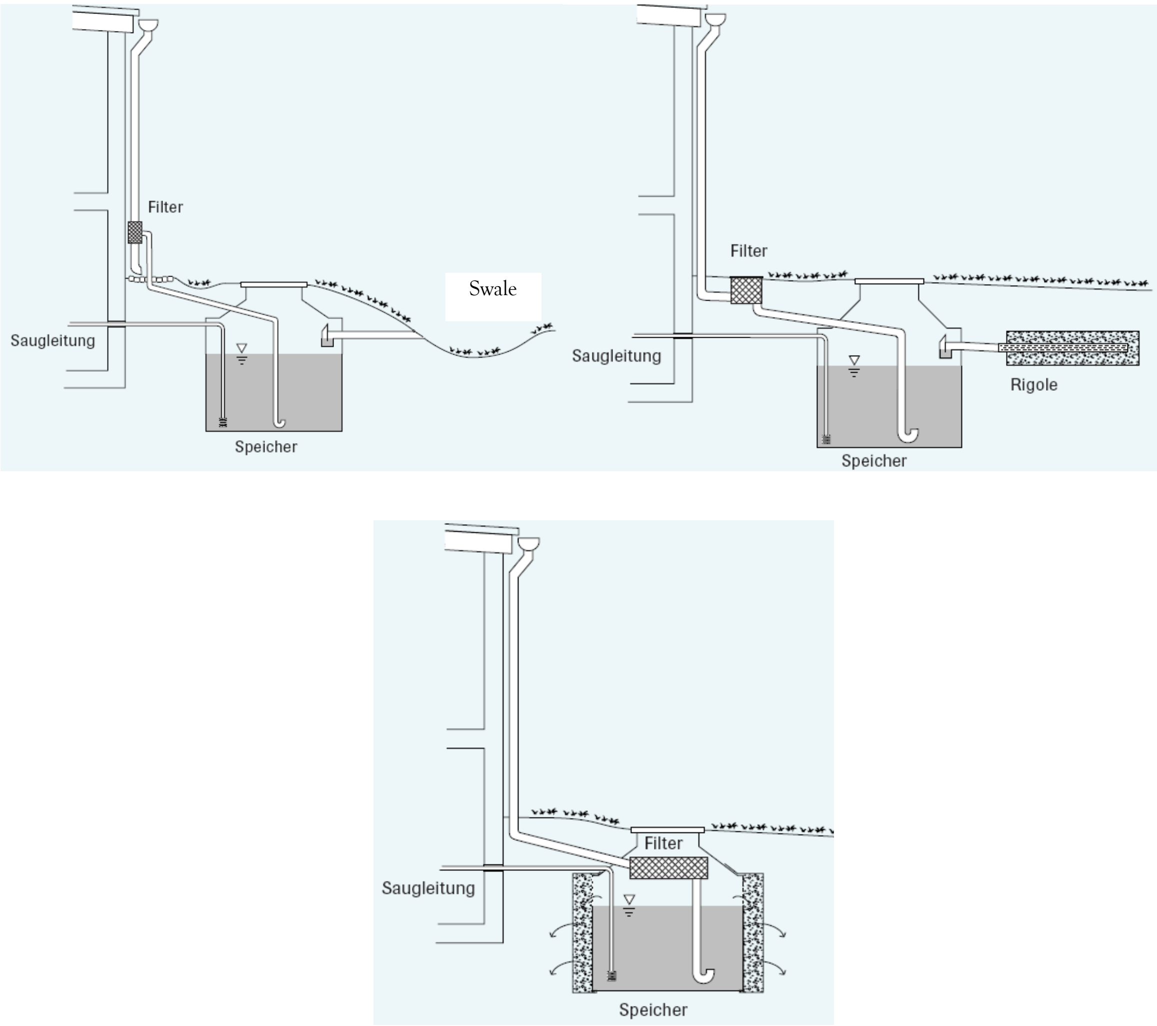


Figure 15 Possibilities of combination of a RWH system and an infiltration device

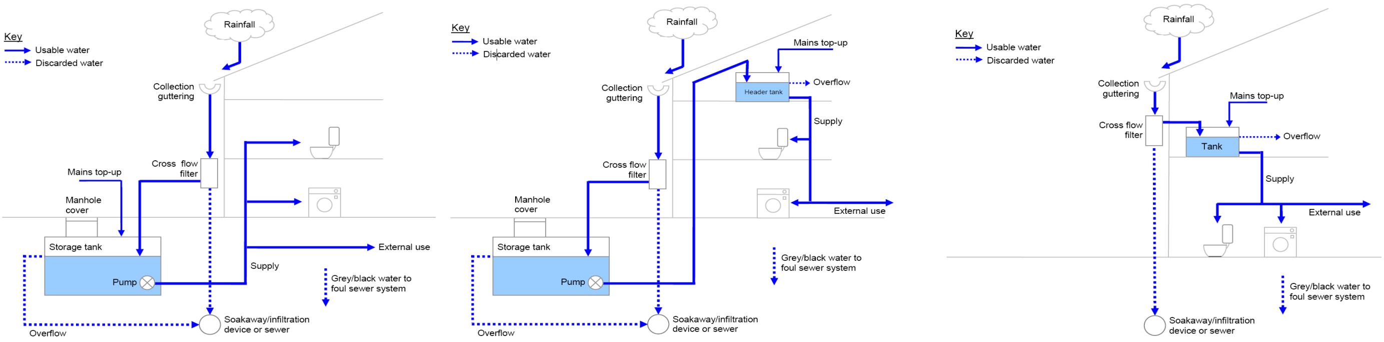
3.1.4 Location of the reservoir.

In order to supply non-potable water to buildings for internal and external uses, Leggett et al. (2001) identified different basic types of system:

* Directly pumped,

* Indirectly pumped,

* Gravity fed.



Directly pumped RWH system *Indirectly pumped RWH system* *Gravity fed RWH system*

Figure 16 Potential locations of the reservoir

They imply different utilizations of energy according to the location of pumps or to the absence of pumps (gravity fed) as illustrated by the opposite figures [*Roebuck, (19)]*

In most cases, underground storage directly pumped is implemented. The gravity fed RWH system has indeed the main disadvantage that the water pressure is likely to be less than that of the mains supply, resulting in poor performance of some appliances (toilet flushing, washing machines) [*Roebuck, (19)*]. Besides, contrary to gravity fed system, direct systems do not require any particular space in the building's roof.

3.1.5 Range of applications per size

On top of these classifications, another one can be introduced regarding the scale of the type of application. Three scales have been selected for this study: households (up to 50 inhabitants), large public and demonstration buildings (schools, sport stadiums, exhibition centres, etc.), and urban stormwater runoff harvesting (e.g. square, open parkplaces, etc).

Important firms have already implemented RWH systems for 20 years and now, small businesses come gradually up with the idea of these systems as well. The process water recycling generates an enrichment of the water in unwanted components, such salts accumulation, which are hardly removed with simple filters. As a consequence, a minimal renewal of water within the process is required. The reuse of salt-free rainwater could be one of the solutions to that problem: it could indeed dilute this water enriched in salt. In addition, industrials are requested by governments to manage their water process in a sustainable way. RWH may be an economical and also environmentally sound approach to address the management and optimisation of industrial water systems.

3.1.6 Needs of norms

When considering all the possibilities that can be implemented with a RWH system, norms and standards appear to be a necessity in order to insure proper functioning of the system and of water quality. There are no overall water reuse standards for the entire European Union and the EU might be considered to be behind in establishing formal guidelines and standards for non-agricultural purposes [*Rachwal, 2008, (7)*], but some countries have however adopted guidelines or regulations (Germany) and some other are currently working on it (France).

Some countries do not have precise standards and norms but they implement new water strategy encouraging use of sustainable water resources such rainwater. That is the case in the UK where several strategies have been published: *Directing the flow* (Department for Environment, Farming and Rural Affairs – Defra – 2002), *Water resources for the future* (Environment Agency – EA – 2001), *Water for the people and the environment* (EA, 2007), *Water Efficiency in the South East of England-Retrofitting existing homes* (EA, 2007b).

Two main types of norms in Europe have been highlighted and are presented in the following paragraphs: norms concerning design, technical and operating aspects, and norms regarding water quality.

3.2 Norms regarding design and technical aspects

3.2.1 Europe

EU-Guideline 91/271/EWG, 1976: collection, treatment, discharging of local waste water (such rainwater and industrial water). It concerns mainly pipes.

3.2.2 Germany

The most important norm in Germany dealing with this field of application is the DIN 1989 (DIN stands for Deutsches Institut für Normung). This norm resulted from the common work of representatives from the private sectors, government agencies and water and resource management associations (among others, the fbr). DIN 1989 applies to rainwater utilization in the domestic sector and to commercial and industrial applications. It should be noted that this norm takes into account the previous DIN dealing with rainwater (1986, 1988, ATV Arbeitsblatt and so on.).

This standard is composed as follows:

* Part 1 – DIN 1989-1: Planning, design, operation and maintenance

* Part 2 – DIN 1989-2: Filters

* Part 3 – DIN 1989-3: Rainwater storage and reservoirs

* Part 4 – DIN 1989-4: Controls and monitoring systems

Regarding the design and technical aspects, the whole DIN 1989 includes these aspects since its different parts provide manufacturing standards (design, materials and so on) for the various components that make up a system, including testing procedures.

The following guidelines can be mentioned in addition to the DIN 1989 to provide the overall perspective:

EU-Guideline 2000/60/EG, 2000: EU Water Framework Directive

Water supply act, 2002 (Wasserhaushaltsgesetz)

Waste water decree, 2004 (Abwasserverordnung)

Berlin water act, 2005 (Berliner Wassergesetz BWG)

Ordinance on installation for handling of substances hazardous to waters and on water service, 2006 (Verordnung über Anlagen zum Umgang mit wassergefährdenden Stoffen und über Fachbetriebe VawS)

Ordinance on waste water pipes in public waste water installations, 2005 (Indirekteinleiterverordnung – IndV)

Ordinance and carte on the free authorization for free-of-damage rainwater infiltration, 2001 (Niederschlagswasserfreistellungsverordnung – NWFreiV)

Guideline on groundwater conveyance during building measures and appropriate water supply facilities in Berlin, 4/10/1999

Convention for water use service, Senatsverwaltung für Stadtentwicklung (Rundschreiben SenStadt VI Nr. 1/2003)

3.2.3 Australia

The design of stormwater and rainwater reuse practices may have to consider Australian Standards such as AS3500.1.2. Water Supply [*Coombes and Kuczera, (21)*]. Cross connection between water supply mains and premises with a rainwater tank is described as a low hazard, indicating that rainwater can be considered to be potable.

The enHealth Council, a subcommittee of the National Public Health Partnership, published in 2004 a comprehensive guide, namely *Guidance on use of rainwater tanks (22)*, which includes all aspects of rainwater harvesting: design, quality monitoring and maintenance as well.

The Stormwater Industry Association and Urban Water Resources Centre at the University of South Australia provide a handbook of source control stormwater detention and retention system (quantity and quality, design, detail for Aquifer Storage and Recovery System)

3.3 Norms regarding water quality

3.3.1 General guidelines

Concerning water quality and sanitary aspects, guidelines concerning the use of wastewater published by the World Health Organization (WHO) have to be considered.

3.3.2 Europe

EU-Guideline 76/464/EWG, 1976: water protection guideline, deals with pollutants, contamination, etc.

EU-Guideline 76/160/EWG, 1976: bathing water quality.

EU-Guideline 96/61/EG, 1996: Guideline concerning the integrated prevention and decrease of environmental pollution.

Drinking Water Directive (EU, 1998).

EU-Guideline 2000/60/EG, 2000: EU Water Framework Directive dealing with surface water, transitional waters, coastal waters and groundwater protection and encouraging sustainable uses of water.

3.3.3 UK

Act of the UK parliament SI No 3184, 2000: adaptation of the European Union Drinking Water Directive.

3.3.4 Germany

DIN 1989 has also to ensure that quality of existing potable water is maintained. That is the reason why the supply network with an “open outlet” has to be completely separated from the potable water network. Identification of pipes network has to be clear: self-adhesive coloured tape with the words “no drinking water” or “rainwater” at short intervals is to be attached.

Drinking Water Ordinance 2001 [TrinkwV 2001]: the amended drinking water ordinance, which is based on European Directive 98/83/EG of the Council for the Quality of Water for Human Consumption, dated November 3, 1998 (ABI EG No L330, 32), became law in Germany on January 1, 2003. There are no restrictions on the use of rainwater but when rainwater is used as process water in rented properties, an alternative connection to the potable water network must be provided for washing machines.

These regulations specify that health authorities must monitor process water systems in public facilities.

Rainwater from installations complying with DIN 1989 requirements is usually of better quality than the European Authorities demand for lakes used for swimming. [*Hollaender, 1996*]

3.3.5 Australia

Handbook of the Stormwater Industry Association and Urban Water Resources Centre at the University of South Australia concerning source control stormwater detention and retention system (quantity and quality, design, detail for Aquifer Storage and Recovery System)

Chapter 4

Selected projects

4.1 References of selected projects according to their location

	Berlin	Germany	Europe	World
Households			E3	
Large Buildings	B3	G1	E1	W2
	B4		E2	
Urban Areas	B1			W1
	B2			

4.2 Berlin

4.3 Germany

4.4 Europe

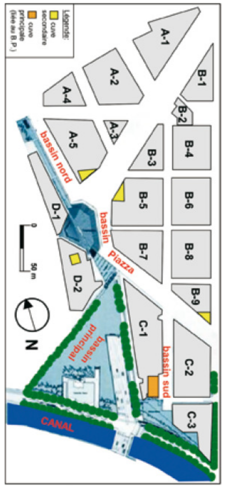
4.5 World

1. Background of Rainwater Harvesting

After the Fall of the Wall, the idea of a space area assembling East- and West-parts of the town generated the Potsdamer Platz project. This area is 7 ha large and includes 19 buildings, 10 public roads and a pedestrian square. The team of Renzo Piano, architect in charge of the project, decided to give a value to this site thanks to water basins. Because of economical and environmental reasons, the use of Drinkwater for basins was judged to be impossible. That is the reason why a Rainwater Harvesting System was designed.

With 1,2 ha surface area of basins is the management of Rainwater in Potsdamer Platz first aesthetic, but Rainwater enables as well to save Drinkwater by its use for toilet flushing and garden watering (for the buildings and green areas all around the square). The planning of the square also has a retention function which allows meeting requirements of the City of Berlin. Berlin demands indeed, for planning with strong sealing, a 3 L/s/ha limited reject of runoff in the Landwehrkanal. Eventually, around 27% of the roof surface area is composed of green roofs.

The project was planned in 1994 and constructed around 1997 and 1998. It should be stressed that this project is one the largest European project, if not the largest, concerning rainwater management and has been in operation since a decade.



2. Implementation of the project - Previous study

A previous study was carried out in order to assess the needs and resources of the area. It has been showed, with a simulation based with 530 mm/year of rainfall, that the potential resource was superior to 18.000 m³.

3. Rainwater Harvesting System

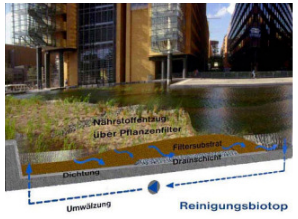
3.1. Overall technical description

3.1.1. Collect and storage

Rainwater is gathered from roofs of 19 buildings with a whole surface area of 44.000 m² including 12.000 m² of green roofs and 32.000 m² of concrete, gravel, glass terraces...A part of this Rainwater is either retained by green roofs or evaporated. Water which has not been retained is then lead in one of the 5 existing tanks (with different volume capacities, from 350 m³ to 1.200 m³). The facility has a total useful capacity of 2.600 m³. Strong stormwater can be managed thanks to a 900 m³ buffer tank.

In addition, external basins are in charge of the main retention of Rainwater on site, thanks to their important surface area and their variability of level.

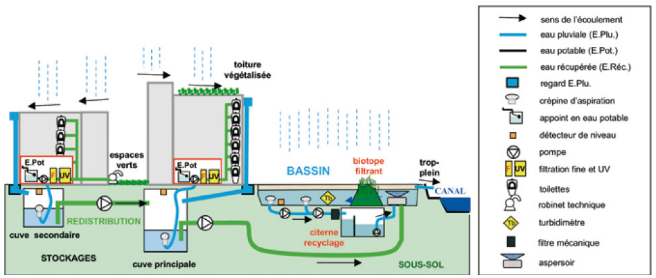
3.1.2. Treatment



Treatment of rainwater in Potsdamer Platz is carried out in a sustainable way thanks to a biotope. Rainwater is purified with an association of filtering plants and substrates. Then, it goes through a recirculation system composed of a filter, a sedimentation tank, a storage and a pumping system.

3.1.3. Use of Rainwater

Rainwater collected here is at disposal for toilet flushing and garden watering and is able to provide 415 WCs, 226 urinals (around 80 % of the needs for toilet flushing) and the irrigation of 3800m^2 surface area as well. A system of pipes and pumps enables the supply of the stored Rainwater.



3.2. Monitoring - Results

Software is collecting all information such as tank levels, pumps running, pH, Phosphor so that water quality and quantity may be monitored overall the facility.
Regarding maintenance, since financing is based on a private-public partnership between the City of Berlin on one hand and the Companies Daimler Chrysler and Debis Immobilier on the other hand, it was decided that the private partners were in charge of maintenance until 2008 and then will be followed by the City of Berlin.
Maintenance consists mainly in cleaning daily basins (removing rubbish, algae, etc.) either by technicians, or by natural means such as carps.

Figures:

Urban water	1,2 ha
Purification biotope	1 670 m^2
Artificial lake	13 000 m^2
Cisterns (5)	2 600 m^3

Connected roofs	44 000 m^2
Percent of green roofs	27 %
Buffer tank	900 m^2
Stormwater retention	3 100 m^2 84 mm

Contacts:

Architect	Renzo Piano	italy@rpbw.com
Master Builder	Atelier Dreiseitl	info@dreiseitl.com

Main reference:

Innovative Wasserkonzepte – Betriebswassernutzung in Gebäuden, Senatsverwaltung für Stadtentwicklung – Berlin, 2003. (2)

1. Background of Rainwater Harvesting

This project consists of a redevelopment of a building complex initially established in the 50ies. It has turned into a residential area, supplied with water-saving sanitary technologies and the buildings were connected to previous wastewater and rainwater sewers. However, the heavy sealing and the unfavourable infiltration conditions encourage the remedy of Rainwater Harvesting System. That is how a rainwater reuse scheme was completed in 1999 and since March 2000, a second pipeline network has been set up and tested by dyeing the service water network in order to make sure that there were no connections with the drinking water network.

The main specificity of this Rainwater Harvesting project is that this plant is probably the first plant worldwide where first-flush entering into the rainwater reservoir comes from the strongly polluted rainwater draining the public streets.

2. Rainwater Harvesting System

2.1. Overall technical description

2.1.1 Collect and storage

In that case, rainwater is collected mainly from roofs (63%) and from public roads (37%) which represents around 11 773 m² surface area. Rainwater is first discharged into the existing rainwater sewer of the Berlin water company, before draining from there into the rainwater reservoir, until the reservoir reaches its full capacity of 180 m³ (i.e. 15 mm or 2,6% of the annual precipitation).

The reservoir is located underground, in the basement of one of the buildings. When the water level of the reservoir attains the sewer level, excess water is discharged into surface water.

2.1.2. Treatment

Rainwater is subsequently treated in a modified constructed wetland inside the building.

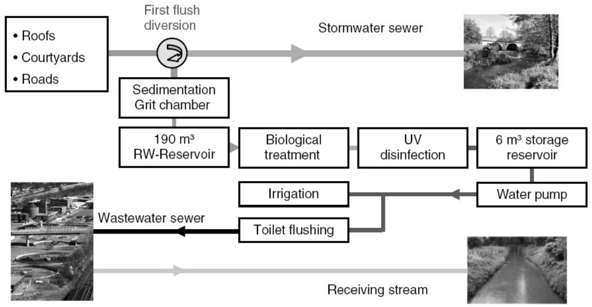
This wetland consists of a "planted" substrate filter of 2,5 m². The filter is made of two lanes which are each 2,2 m long, 1,1 m wide and 0,7 m deep. The above layer consists of expanded clay particles (8-16 mm grain size), while the lower layer is filled with gravel (4–8 mm). The two lanes are placed 1 m away from each other.

Rainwater percolates from above continuously and uniformly over the whole substrate bed. This biological purification is able to treat 10 m³ rainwater daily. Water is then disinfected by UV radiation before being used.

2.1.3. Use of Rainwater

This process is able to supply 87 flats, that is 200 tenants, which represents one third of the whole inhabitants. The purpose of this rainwater is to supply toilet flushing and lawn irrigation.

Process chart of the installation:



2.2. Monitoring – Results

Within the scope of the work group "Environmental Hygiene" of the Technical University of Berlin, some studies were conducted concerning, among others, the service water quality of the system since 1999. The plant was found failsafe and widely accepted by the tenants. Potential high-polluted rainwater can be therefore efficiency treated with an energy requirement of 0,85 kWh/m³.

Figures:

Storage capacity	180m³		
Total daily water use:	9,9 m³ (i.e. 311mm/a)		
Irrigated areas	1100m²		
Connected roofs	7325 m²		
Constructed wetland for rainwater treatment	2,5 m²		
Connected streets and parking lots	4450 m²		
Proportion of total precipitation used	31%		
Catchment Area (CA)	11.773m²		
Percent of green roofs (RG)	<2		
Booster station	3 multi-stage pumps, 200-litre pressure compensation vessel		
Cistern size	180 m³	15 mm	2,6 %AP

Contact:

Company: GSW klaus.wisniewski@gsw.de

TU Berlin: Erwin Nolde erwin.nolde@t-online.de

Main references:

* *Innovative Wasserkonzepte – Betriebswassernutzung in Gebäuden, Senatsverwaltung für Stadtentwicklung – Berlin, 2003*

* *Possibilities of rainwater utilisation in densely populated areas including precipitation runoffs from traffic areas. – Erwin Nolde – 8.10.2006, (23)*

1. Background of Rainwater Harvesting

The Institute of Physics of the Humboldt University Berlin resulted from an architectural competition held in 1997 and was supported financially by the Federal Republic of Germany as a joint initiative for the construction of universities. This project is a combination of stormwater management with energy saving and includes a sustainable concept of construction.

Since impermeable surfaces (roofs, streets…) generate a potential increase of temperature around buildings, use of greening façades and roofs could help to solve this problem. That is the reason why rainwater here is used to irrigate a greening façade and to generate evaporative cooling in air conditioners.

Due to the fact that this building is not connected to wastewater or rainwater sewers, the main purpose of Rainwater Harvesting in that case was to reuse and dispose rainwater on site.

2. Rainwater Harvesting System

2.1. Overall technical description

2.1.1. Collect and storage

Rainwater is collected from roofs (that is a 4700 m² surface area, 6,4% of roofs are green roofs) in five cisterns in two courtyards of the building with a total capacity of 40 m³.

In case of heavy rainfall, stormwater is managed inside the building thanks to a pond (225 m²) located in a courtyard. Water collected in the pond can afterwards evaporate or drain into the ground. This drainage is only allowed through surface areas with vegetation in order to protect ground water from pollution.

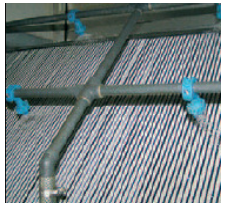
2.1.2. Use of Rainwater

- Green façades

As said previously, Rainwater is used to irrigate 151 m² of green areas, such as green façades. These façades present several advantages. For instance, plants are able to provide shade during summer and they let pass the sun's radiation through the glass front in winter as well. In addition, plants generate evapotranspiration thus improving the microclimate inside and around the building. The behaviour of plants influences the energy consumption of the building.

The selection of plants was depending of their capacity to grow under extreme conditions and to have an adequate capillary climbing aptitude. The Wisteria sinensis meets these requirements.

- Adiabatic Cooling Systems



The building is equipped with 8 adiabatic cooling systems. The process of such systems consists in spraying rainwater on the building's exhaust air whereby fresh air entering the building is cooled through a heat exchanger. It enables to cool down air to a temperature to 21 – 22°C whereas outside temperature is around 30°C, and without using any other technical cooling systems.

2.2. Monitoring – Results

As a project of the Berlin Programme for Urban Ecological Model Projects commissioned by the Berlin Senate for Urban Development, it has been monitored and evaluated by a working team of experts from the TU Berlin, the Humboldt University and the University of Applied Sciences Neubrandenburg.

It has been shown that the evapo-transpiration of 1 m^3 of water produces an evaporative cooling with a value of 680 kWh. It should be stressed that rainwater can be used for different systems in the meantime such as for both irrigation and adiabatic cooling. In addition, the energy consumption of the building was reduced by more than 67% thanks to the use of adiabatic system.

Other factors have been monitored as well, namely: water consumption of different plant species, effects on the overall energy consumption of the building, irrigation, temperatures and radiation.

Figures:

Storage capacity	40 m^3		
Adiabatic cooling system	7		
Irrigated green areas	151 m^2		
Connected roofs	4700 m^2		
Pond in the courtyard	225 m^2		
Catchment Area (CA)	4700 m^2		
Percent of green roofs (RG)	6,4%		
Consumption	5,1 m^3/d	412 mm/a	
Stormwater retention	180 m^3	40 mm	
Cistern size	40 m^3	8,9 mm	1,5%

Main reference:
Institute of Physics in Berlin – Adlershof – Urban Ecological Model Projects – Senatsverwaltung für Stadtentwicklung (24).

Contacts:

Architects: Georg Augustin augustin_und_frank@t-online.de
Ute Frank

Project Manager:
Dipl.-Ing. Brigitte Reichmann brigitte.reichmann@senstadt.verwalt-berlin.de

Scientific Monitoring:
TU Berlin Prof. Dipl.-Ing. Claus Steffan claus.steffan@tu-berlin.de

TU Berlin Dipl.-Ing. Marco Schmidt marco.schmidt@tu-berlin.de

1. Background of Rainwater Harvesting

Since 1979 environment-friendly concepts have been developed in Ufa-Fabrik, an old film factory turned into a cultural centre. Many new ecological concepts are exhibited in this place. Among these concepts a rainwater management system is investigated.

The first measure undertaken in the frame of this rainwater management was the building of green roofs and façades in 1980. It was the first project of decentralized approach for urban greening in Berlin as well. Primarily, the aim of such green areas was to enable a better evapo-transpiration of plants. Missing vegetation generated indeed a lack of evapo-transpiration, thereby increasing *the thermal radiation caused by higher surface temperatures of hard materials like concrete and the ability of such surfaces to store heat* [Schmidt, 2005]. Rainwater projects concerning evapo-transpiration were therefore implemented and rainwater has been used since for toilet flushing and irrigation.

2. Implementation of the project – Previous study

The estimated needs of the Ufa-Fabrik for toilet flushing and irrigation amount to 3.000 m³ per year. With a mean value of 500 mm/year of rainfall and thanks to a catchment area of 7.600 m², around 4.000 m³ of rainwater can be used which means that the estimated needs could be entirely supply with rainwater.

3. Rainwater Harvesting System

3.1. Overall technical description

3.1.1. Collect and storage

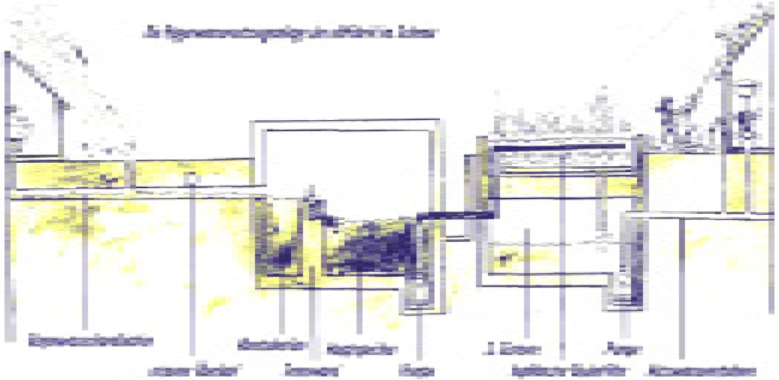
Once green surface areas were set up in 1983 to 85, a rainwater harvesting system was integrated in 1994. Rainwater and first-flush stormwater are collected from roofs with the runoff of streets and is stored in a former underground waterworks station. This station has a total storage capacity of 240 m³ (i.e. 6,7% of the annual precipitation) and is composed of a sedimentation tank (20 m³), a main reservoir (220 m³) and a service water tank of 20 m³. The rinsing water from the Café is added in the process in the sedimentation tank.

3.1.2. Treatment

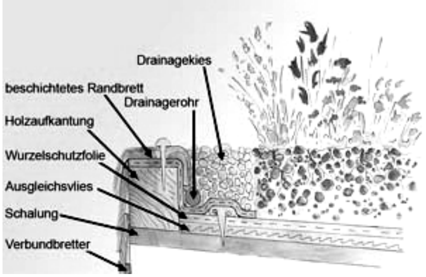
As the first-flush stormwater is highly polluted, a water treatment is required before being provided for toilet flushing and irrigation. This treatment is carried out by means of a modified constructed wetland (25 m²).

3.1.3. Use of Rainwater

Taking into account the fact that all the rainwater from rainfalls is not available, due to pollution, losses, etc., it has been evaluated that this rainwater can only provide 72% of water used in the community (then 28% is supplied by the public drinking water network), whereas it was thought that all the needs could be provided by rainwater. This corresponds to the supply of 30 toilets and around 8.600 m² of irrigation thanks to centrifugal pumps.



Green roofs



Green roofs in Ufa Fabrik have shown that 58% of the radiation balance can be converted into evapo-transpiration during summer months whereas non green roofs can convert 95% of the radiation balance into heat.

3.2. Monitoring and results

As the first significant project in Berlin concerning green roofs and façades, many studies have been investigated by the TU Berlin regarding the ability of green roofs to retain stormwater, pollutants and their air-conditioning feature as well.

Figures:

Storage capacity	240 m^3 in two cisterns		
Irrigated green areas	8600 m^2		
Catchment Area (CA)	7600 m^2		
Percent of green roofs (RG)	34%		
Overflow	Teltow canal		
Consumption	6,3 m^3/d	380mm/a	
Pump	5 centrifugal pumps		
Cisterns	240 m^3	40mm	6,7%AP

Other ecological concepts in Ufa-Fabrik
Light
Acoustic
Windmill
Photovoltaic
Building control
Block heat and power device
Climate friendly air conditioning
Selective waste-sorting/Composting

Contacts:		*accessed on 01.08.2008*
UFA Fabrik	oekologie@ufafabrik.de	www.ufafabrik.de
TU Berlin	Marco Schmidt	marco.schmidt@tu-berlin.de

Main reference: Innovative Wasserkonzepte – Betriebswassernutzung in Gebäuden – Senatsverwaltung für Stadtentwicklung.

1. Background of Rainwater Harvesting

In Response of an architecture contest for the buildings of an insurance company, the architects Dürschinger and Biefang won the first price by proposing a futurist and "poetic" project with the collaboration of the Bureau of Adler & Olesch. 2700 Employees could benefit then from an environment where rainwater management is taken into account with a new concept of rainwater retention and use. This project has been carried out in two steps; the first was completed in 1998 and the second one in 2000.

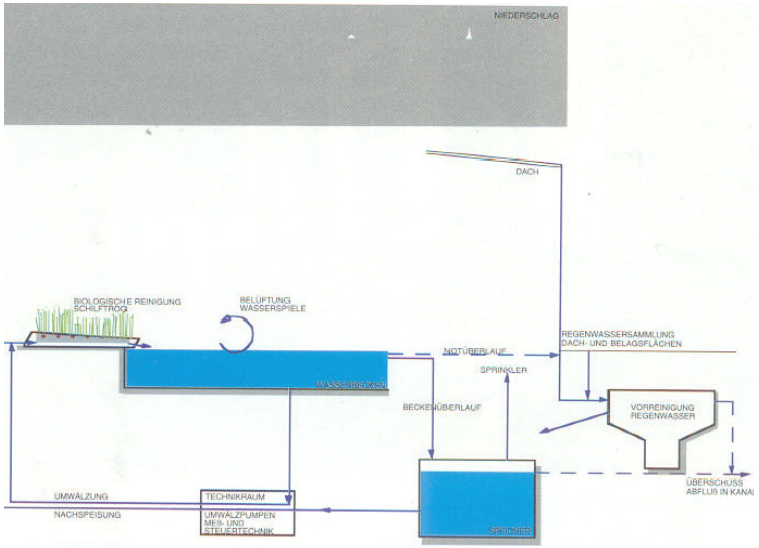
One of the specificity of this project is that it combines a Rainwater Harvesting system with a stormwater management. That is to say that not only is the rainwater used for fire fighting and cooling the buildings but the rainwater is retained thanks of many means such as retention basin, green roofs and reeds bed as well.

2. Rainwater Harvesting System

2.1. Overall technical description

2.1.1. Collect and storage

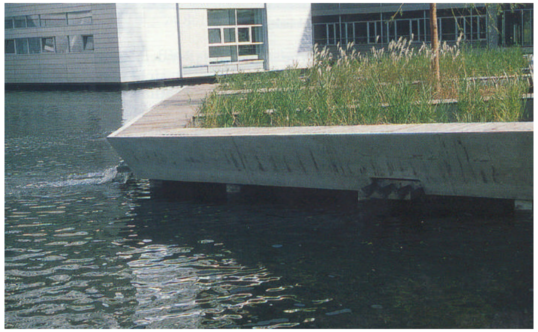
Rainwater is collected from the roofs of the buildings and is first discharged in a concrete tank. Roofs and other collection surface area represent here 21.500 m^2 whose 2.200 m^2 are green roofs. Then it is lead thanks to pumps in a 1,5 m deep water reservoir including a reeds bed. The flow rate inside the cycle of this process can be adjustable so that it matches the demand, thanks to 6 pumps with frequency converters. The overflow is discharged to the local canal.



2.1.2. Treatment

The aim of the architects was to implement a sustainable process for the treatment of the rainwater collected. This implies not to use chemistry. The reeds bed enables hence to purify and filter the rainwater continuously.

In order to stabilise the biology of water, other methods have been implemented: independent flow and mix between areas with different temperatures (obtained thanks to the depth of water and with shadow areas), additional flow and oxygenation with water games, pH stabilized around 5-6 (natural pH of rainwater and contact with the concrete of the tank). Due to the fact that this treatment depends on water temperature, a water temperature boundary has been imposed to 24°C, which can be obtained just in case of extreme and long heat.

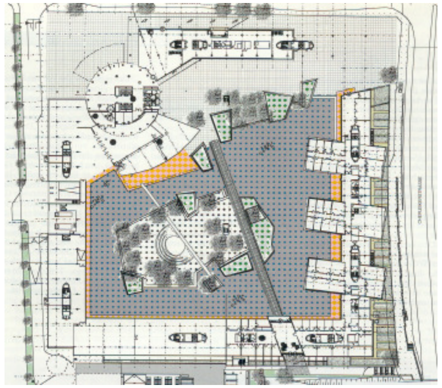


2.1.3. Use of Rainwater

Rainwater in this project is first used for fire fighting with a volume of 380 m³ dedicated for this task. But thanks to the stormwater management, other energy compensation aspects have been enhanced: cooling local area by evaporation, energy savings with using the reflecting light on the water instead of public light use…

2.2. Monitoring – Results

Step of building	1st step	2nd step
Completion	1998	2000
Water surface area	4300 m²	3500 m²
Depth of water Whose max. rainfall buffer	1,5 m/1,3 m 0,2m	1,5 m 0,2 m
Volume of basin Whose max. rainfall buffer	6 200 m³ 860 m³	5 250 m³ 700 m³
Water tank Whose max. rainfall buffer Whose fire fighting storage	480 m³ 400 m³ 80 m³	1 000 m³ 700 m³ 300 m³
Reeds bed area	240 m²	310 m²
Pumps with frequency converters	6	4
Annual rainfall in Nürnberger	600 – 650 mm	
Total catchment area Whose green roofs	21 500 m² 2 200 m²	
Max. retention volume	12 930 m³	
Cost of building (without VAT for water technic)	4 Mio. DM (around 2 Mio. €)	



Contact: *accessed on 15.08.2008*

Adler & Olesch www.adlerolesch.de
kontakt@adlerolesch.de

Main reference: Neubau mit 12 930 Kubikmeter Regenspeicher – Klaus König – IKZ HAUSTECHNIK, Heft 23/98 (25)

1. Background of Rainwater Harvesting

Forum Chriesbach is owned and is used by Eawag, the Swiss Federal Institute of Aquatic Science and Technology. This research institute develops long-term solutions for fundamental problems (among others: management of water, energy, soil…) so that Eawag is concerned with all natural resources. In order to meet the institute's principles, the Forum should be "a visionary concept regarding ecological sustainability".

As a consequence, water resources are managed in a sustainable way. Besides using Rainwater Harvesting practice, runoff management is implemented.

2. Rainwater Harvesting System

2.1. Overall technical description

2.1.1. Collect and storage

Rainwater, as said before, is either infiltrated, either collected for research purposes or gathered from roofs to be used. The water going through roofs is fed into an 80 m^3 pond whose aim is actually to treat this murky rainwater.

2.1.2. Treatment

The pond consists of a triple-chamber biological treatment plant located near the building. Rainwater, after its passage through green roofs, becomes trouble and this pond is a sustainable means of clarifying and treating the water so that it could be used. In case of an overflow, water settles in sumps in the adjacent terrain and seeps gradually into the soil, or ultimately to the adjacent creek..

2.1.3. Use of Rainwater

The treated water is taken from the second settlement chamber and is piped back into the building in order to supply toilet flushing.

Rainwater which concerns no drinking purposes enables the scientific centre of competence Eawag to investigate studies regarding relationships among rainfall, retention, evaporation and runoff of roof water. Polluted rainwater from roofs with heavy metals and pesticides is as well studied to remedy this environmental problem.

3. Specificities of Forum Chriesbach

Since this building is a research centre, some investigations regarding the integration of separate collection and treatment of urine in urban water-management systems are carried out. The urinals are waterless and toilets use the "No-Mix" concept.

Forum Chriesbach demonstrates an integrated environmental concept as well with other concepts such as climate control, energy efficiency, mechanical systems with the contribution of Empa – the Swiss materials science and technology research institute.
The infiltration is made easier thanks to the porosity of soils and the retention improved with the set-up of green roofs.

Figures:

Volume and areas	Building volume	38 615 m^3
	Atrium volume	4 788 m^3
	Exterior surface area	5 174 m^2
	Main usable floor area	5 012 m^2
	Floor area	8 533 m^2
	Roof area	1 886 m^2
	Energy reference area	8 270 m^2

Building utilities	Photovoltaic panel area	459 m²
	Evacuated heat pipe solar collectors	50 m²
	Thermal storage tank	12 m³
	Rainwater storage tank	4 m³
	Rainwater storage pond	80 m³
	Drinking water consumption	811 m³/a
Energy	Heat capacity demand	8,0 W/m²
	Thermal heat demand	52,0 MJ/m²a
	Heat drawn from Empa Network	23,6 MWh/a
	Cooling drawn from Empa Network	12,0 MWh/a
	Vacuum pipe collectors	24,0 MWh/a
	Power demand (without server)	181,0 MWh/a
	Photovoltaic power generation	60,0 MWh/a
	Power drawn from public grid	12,0 MWh/a
	Gray energy including excavation and mech/elec. Systems	12 000 MWh
	Expected average service life	37,6 years

Contact: *accessed on 15.08.2008*

Holcim Foundation for Sustainable Construction info@holcimfoundation.org
Builder www.forumchriesbach.eawag.ch forumchriesbach@eawag.ch
Architects Bob Gysin + Partner www.bgp.ch admin@bgp.ch

Main reference: Research center in Switzerland – Eawag Forum Chriesbach – Holcim foundation for sustainable construction – 2007 (26)

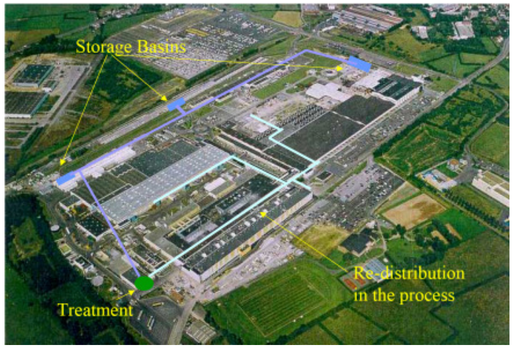
1. Background of Rainwater Harvesting

Maubeuge Construction Automobile (MCA) is a subsidiary of Renault dealing with cars assembling (with a capacity of 60 Kangoos/h). In 1995, a local authority regulation required new water quality standards and MCA was one of the first Renault site complying with this regulation. Thanks to a favourable rainfall situation (on average, 840 mm/year), high water prices (1€/m³ under a 200 000 m³ consumption, 0,6€/m³ over this limit) and the willingness of the firm to integrate its water management in a sustainable management of water resources, a system of Rainwater Harvesting was designed to supply over 50% of the industrial consumption and in consequently to save water. The other purpose of this system was to reduce potential pollution due to rainwater by the diffuse and accidental pollutions prevention and decontamination thanks to a natural settling.

A stormwater reuse process was therefore built from November 1997 to July 1999 including collection, storage, treatment and distribution of treated water and was experimented during one year (from June 1999 to June 2000). This project was supported by 97% as a European-life project (LIFE97 ENV/F/000183) and was performed in partnership with Vivendi Water Anjou.

2. Implementation of the Project – Previous study

Renault had undertaken a study regarding its water networks and discharges. The conclusions of this diagnosis were that the prevention of industrial pollution at the source should be carried out at the same time with a strategy for diminishing water consumption in order to be efficient and that the building of basins or natural decanting was the best cost-effective technology.



3. Rainwater Harvesting System

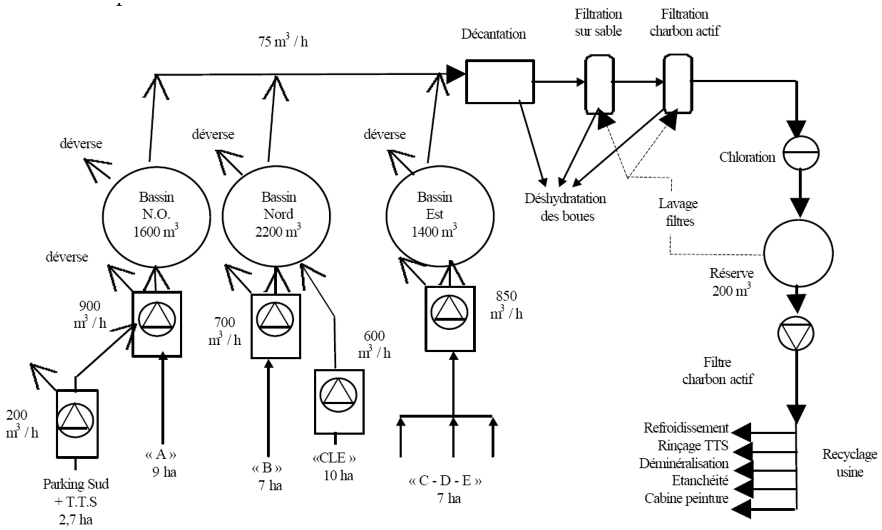
3.1. Overall technical description

3.1.1. Collect and storage

Rainwater is collected all over the site from roofs. The catchment area represents 50% of the whole surface area (77 ha with 19 buildings), i.e. 39ha. It is then stored in 3 basins close to raising stations with a total capacity of 4 000 m³ and finally lead to a settling tank

3.1.2. Treatment

This water is transported to a treatment station including classical water treatment process. It consists of a settling tank, a sand filter, an active carbon filter and a disinfection tank.



3.1.3. Use of Rainwater

Rainwater is here used mainly as a water process such as surface treatment rinsing and demineralization.

3.2. Monitoring – Results

The main stake of this project was to collect technical and economical data from this on site operating experience so that a design software could be developed.

Consequently, SIRRUS – Software for Industrial Rainwater ReUSe – was created in order to evaluate the technical feasibility and calculate the profitability of stormwater reuse. It would be afterwards applied for other industrial sites. The input parameters were, for instance, the average annual rainfall, water price, the employee number… SIRRUS was able to determine the potential reuse volume of rainwater, the return on investment period…

The MCA project was successful: the quantity of drinking water was reduced, 160.000 m³ of water were recycled from rainwater, saving 50.000 € per year while covering the production cost. The quantity of polluted rainwater going into rivers diminished as well. Thanks to SIRRUS, other projects were implemented on Renault sites.

Catchment Area	39 ha
Tanks (3)	4000 m³
Treatment	Classical water treatment
Investment	2,5 MF returned on 2-3 years

Contacts:
Project: Jean-Sébastien Thomas Anjou-Recherche
jean-sebastien.thomas@generale-des-eaux.net

Main reference: Recyclage des eaux pluviales: l'expérience opérationnelle de Maubeuge Construction Automobile – Le Pol et al. 29.05.2000 (27)

1. Background of Rainwater Harvesting

These last years, supply and demand concerning Rainwater Harvesting have increased in France, for domestic purposes (such as toilet flushing), indoor and outdoor. Moreover, the growing sealing of urban soils hales municipalities to respect the new regulations concerning Rainwater management: infiltration compulsory, retention with limit flow rate…

This experimental household has hence as principal objective to evaluate the main features of a domestic Rainwater Harvesting installation. It consists of simulating the human occupancy by – among others - heat contribution, pollutants emissions, light simulating and studying qualitatively and quantitatively the use of rainwater for one use: toilet flushing of a 4persons household.

2. Implementation of the project – Previous study

The installation was defined by the Centre Scientifique et Technique du Bâtiment (CSTB). MARIA (which stands for Automated House for Innovative Researches concerning Air) was designed for the occupancy of 4 persons all year long and equipped with "hydro-economical" devices (limited volume of flush and double order 2 x 1.500L). An apparatus measuring the evacuated volume by the overflow pipe was set up to assess the volume harvested and when the storage is totally full as well.
The whole installation cost 1.000 € and the monitoring device 4.500 €.

3. Rainwater Harvesting System

3.1. Overall technical description

3.1.1. Collect

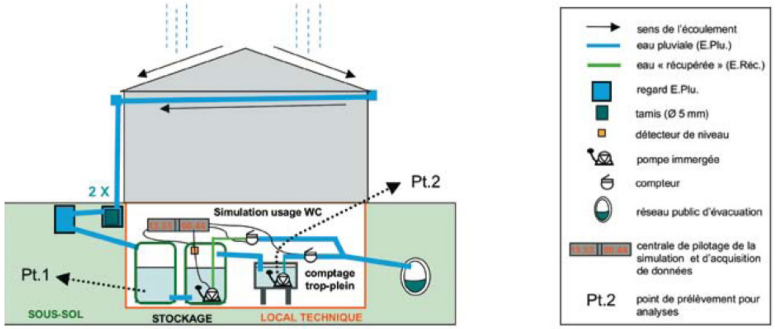
Rainwater is collected from the roof of MARIA which has a 113 m² surface area. This roof is made of lacquered steel tubs; a zinc gutter leads rainwater down to 2 lacquered steel downpipes.

3.1.2. Treatment

Both downpipes ends with a man-hole with a wire basket filtering thus with a 8 mm sieve.

3.1.3. Storage

Rainwater is then lead in a main man-hole made of PVC which is linked with a pipe in PVC to the 2 storage tanks located in a technical room.. These 2 PEHD tanks are connected by their bottom and provide a total capacity of 2,65 m³.



3.1.4. Use of Rainwater

As mentioned above, the simulation allows studying the use of toilet flushing. A pumps system simulates the water quantities for a 4 persons family with a discharge in

Catchment Area	113 m^2
Roof	Lacquered steel
Tanks (2)	Underground 2,65 m^3 PEHD
Pumps (2)	1st: immersed in 2nd tank 2nd: in order to count the overflow FLYGT STXM2
Filter	8 mm sieve
Harvested used Rainwater	72,4 m^3/year
Assessed demand	26 m^3/year

the rainwater public discharge sewerage. The utilized scenario here matches with a 504 L daily consumption, i.e. 27 daily usages per inhabitant.

3.2. Monitoring – Results

The device includes a weather station (providing information about pluviometry), an UV sensor (measuring water level in tanks), a central processing unit giving parameters with a 15 minutes frequency and a counting system assessing water flows. In order to monitor quality water as well, two sample points were used.
Any particular maintenance was not carried out due to the experimental aspect of this house; dead leaves were just removed from the man-hole.

The quantitative monitoring began in October 2002 and the results of the first operating year could be applied for a household located in the Parisian area with an annual rainfall of around 700 mm. MARIA proved that its design was able to obtain a 95% harvesting rate. Besides, this study shown that for a household with similar design, the optimal capacity of tanks was 2 m^3 when just considering the toilet flushing use. Moreover, 60% of harvested rainwater was discharged in sewerage meaning that further uses could be set up in the device. It is also obvious that this kind of device do not have a retention function.
Concerning qualitative aspects, rainwater collected do not meet the requirement of drinking water; however its quality was near to a bathing water standard although only rough screening was apply in the process. As a consequence, it appeared that Rainwater use do not generate sanitary risks for toilet flushing purpose.

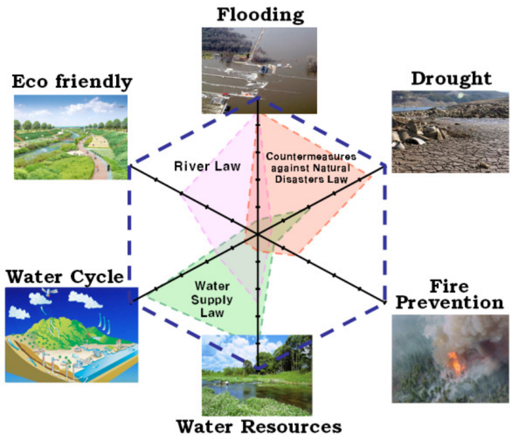
Contacts: *accessed on 12.08.2008*

CSTB
http://www.cstb.fr/pied-de-page/contacts.html

Main reference:
Récupération et utilisation de l'eau de pluie dans les opérations de constructions – CSTB/ARENE(6) -

1. Background of Rainwater Harvesting

Since Korea encounters many water-related problems, solutions such as Rainwater harvesting are investigated. A new water management is therefore implemented in order to tackle flooding, drought, water pollution, dry rivers and mountain fires.
The former solutions such as dams, levees and use of groundwater are not anymore sufficient.
That is why Seoul City promulgated a new regulation to enforce the installation of a rainwater harvesting system in December 2004. A specific rainwater system was set up in a recently constructed building at the Star City Project in Kwangjin-Gu (Seoul) and is an example of a new water concept in Korea called “multipurpose rainwater management”.

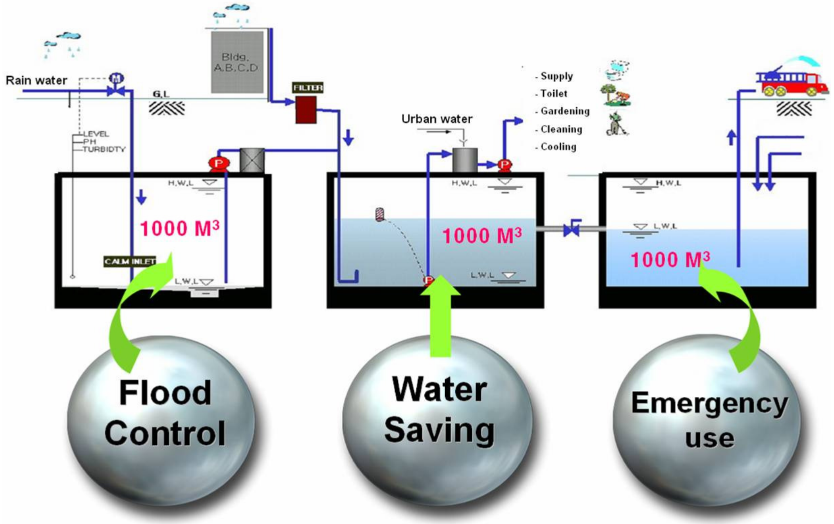


2. Rainwater Harvesting System

2.1. Overall technical description

2.1.1. Collect and storage

A 3.000 m^3 tank is located underground, in the basement of the building, and is divided into three sections of 1.000 m^3 each. The first section collects rainwater from the unpaved surface. The purpose of this first rainwater tank is to mitigate flood events. It should be kept empty most of the time except in case of heavy rain.
The second tank collects rainwater from the roof of the building and the third reservoir is filled with fresh water to be used for emergencies (firefighting or accidents).



2.1.2. Use of Rainwater

Rainwater collected and stored in the second tank is then used mainly for toilet flushing and garden watering. It enables thus water saving which is a concept belonging of the multipurpose rainwater management.

2.2. Monitoring – Results

A software PLC – Programmable Logic Control – monitored the use of rainwater: it has shown that within a period of 2 month, 3774 m^3 of rainwater was stored and used for toilet flushing (25%) and garden watering (75%), and that the stored rainwater was neutral.

Contact :

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Main reference: Proactive multipurpose rainwater management in Korea. – Mooyoung Han.

1. Background of Rainwater Harvesting

Olympic Games give often the opportunity to the organizers to innovate in terms of architectural projects. Once again (as for the Olympic Stadium in Berlin, or the Korean stadia), the new Stadium in Peking (and the other Olympic sites) is a demonstration in terms of ecological building: energy and water among other things are managed in an environmental-friendly way.

Substantial investments have been made in water and sewage treatment, rainwater harvesting and intelligent irrigation systems.

2. Rainwater Harvesting System

2.1. Overall technical description

2.1.1. Collect and storage

The National Stadium's new rainwater recycling system uses underground pools that process up to 100 tons of rainwater per hour and 2.000 tons per day.

2.1.2. Treatment

The partner General Electrics (GE) of this implementation provides a nanofiltration membrane in order to filter rainwater prior to being used.

2.1.3. Use of Rainwater

Rainwater could be used for landscaping, firefighting and cleaning in a water saving purpose

2.2. Monitoring – Results

Since this project is quite recent, no return on experiences is available for the moment.

3. Other water concepts

Other water concepts all around the Olympic sites are implemented. For instance, permeable blocks make up most of the paving at the Fengtai Softball venue allowing thus rainwater to seep through to water collection systems underground.

In the Olympia Media Village, at least 3.000 m^3 of rainwater can be captured using water permeable bricks, pipes and wells installed on roofs, roads and green areas.

Contact :

Lisa Lanspery, GE lisa.lanspery@ge.com
Renata Hopkins, GE renata.hopkins@ge.com

Main reference: www.olympic.org/

Chapter 5
R&D projects

5.1 Introduction

Many research and demonstration projects have been carried out concerning Rainwater Harvesting worldwide. A list of the most significant projects in Europe and worldwide is available in the Appendix A. This literature study draws the attention to six aspects of the current R&D activities who attracts always more attention: drinking water, energy compensation, environmental consequences, economical aspects and integration of stormwater management and RWH. The last aspect concerns hygienic considerations (with among other compensations, the drinking water issue), but it was not the purpose of that report. Moreover, it should be stressed out that the overall lack of return on experiences encountered during this study on the identified demonstration projects does not allow obtaining a comprehensive review and assessment of these projects. The lack of return on experiences is a weakness in the international know-how on RWH practices.

5.2 Drinking water

Since some countries are using water for drinking purposes such as in Australia (see Chapter 2, section 2.3.3.8.), drinking water could be considered as the next step in R&D investigations. However, since the water for drinking purposes represents a non-important part (only 4% in Germany, [*UmweltBundesAmt, 2004, (3)*]) in the total water consumption on household scale, this aspect can not be accounted as a principal driver for the implementation of RWH system in industrialized regions. In addition, the possible sanitary risks for drinking purposes do not encourage these studies in other countries and researches have been only focused to comply with water quality requirements for domestic purposes, i.e. washing machines, toilet flushing and so on.

On the other hand, more treatment concerning rainwater and wastewater to the level of drinking water would imply that the installation of dual pipes to supply two water types of two different qualities would not be required anymore. This consideration is therefore reaching economical aspects (see Chapter 5, section 5.5), as further treatment matching drinking water quality would relate to saving in terms of installation costs.

As an example is the project DEUS 21 carried out with a focus on domestic targets, with the specificity to be investigated on a large scale catchment. Rainwater falling on the new housing estate “Am Römerweg” (100 housing plots at project start) is collected in a subterranean system of storage tanks and fed into a ultrafiltration membrane plant followed by UV irradiation which processes the water to meet the German Drinking Water Ordinance (TVO) standards with regard to contents and hygiene. This water service is continuously monitored. The water is supplied to the households as alternative water source thanks to a separate service water network, laid in parallel to the drinking water supply, but is ultimately thought to be connected to the drinking water supply. Figure 17 represents this process.

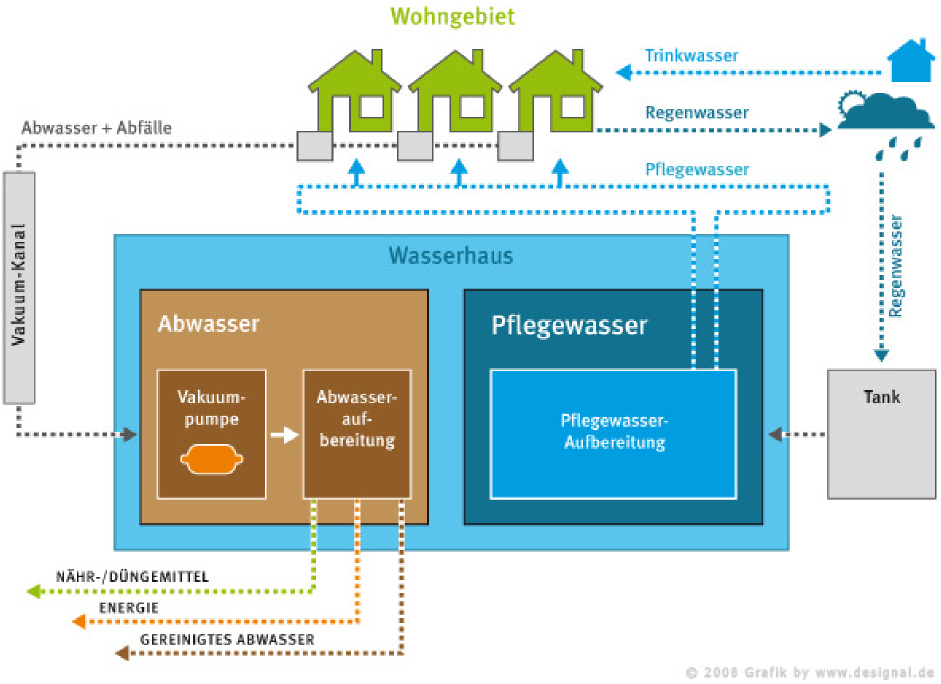


Figure 17 Process of DEUS 21 project [www.deus21.de]

One Australian project, namely Aquifer Storage Transfer & Recovery (ASTR in Salisbury, FP6 project “Reclaim Water”) is currently using RWH from catchment runoff for drinking purposes.

The project will see approximately 200.000 m³ per year of urban stormwater harvested via an engineered wetland within the *Parafield Stormwater Recycling Scheme,* which will be injected into a brackish aquifer with the aim of improving and recovering water to a potable standard [united Water, Research & Development]

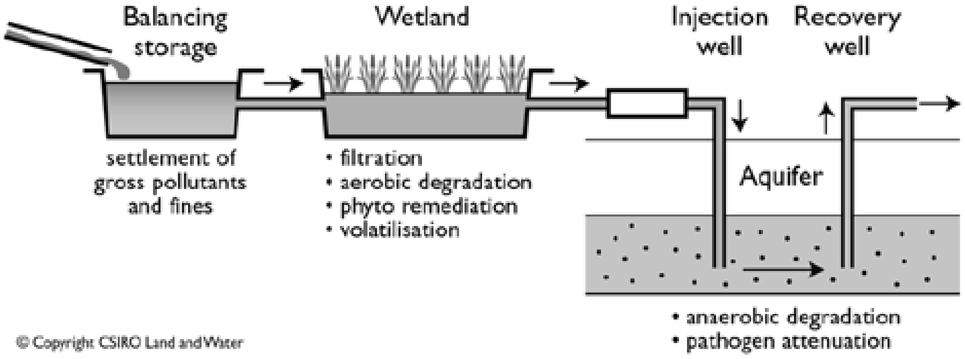


Figure 18 Process of Aquifer Storage Transfer & Recovery [www.clw.csiro.au/research/urban/reuse/projects/astr-salisbury.html]

Traditionally, Aquifer Storage & Recovery (ASR) utilises the same well for injection and recovery. Here, the principle of ASTR is to utilise separate wells for injection and recovery in order to extend residence time of the stormwater within the aquifer and in so doing enhance passive treatment thanks to the limestone and the low-moderate permeability of the aquifer. Afterwards the water will be used to irrigate the surrounding area, and ultimately for drinking water.

The research is focused at understanding the water quality improvements of harvested, injected and recovered stormwater.

5.3 Energy compensation

5.3.1 Energy compensation in cooling systems

One of the main aspects studied in the current R&D projects is the use of rainwater as a sustainable way for cooling large buildings. The Institute of Physics in Adlershof, with his 7 adiabatic cooling systems is one example for a public building. The façade greening at the Institute generates an average cooling value of 157 kWh per day and per façade and the evaporation of one cubic meter produces an evaporative cooling with a value of 680 kWh (i.e. about 70€/m^3).

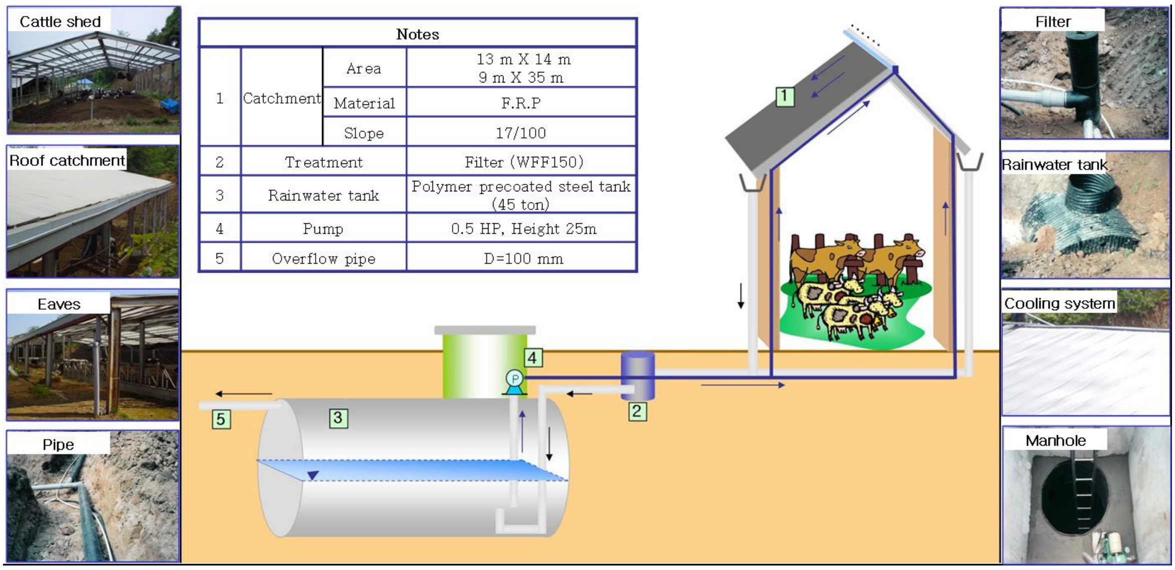
In the frame of this project, rainwater is therefore used in two different cooling systems: adiabatic cooling systems, as described in the fact sheet in the selected projects (Chapter 4), can be defined as an active cooling system, whereas façade greening provides passive cooling by shade and evaporation.

A similar concept is implemented in an agricultural context such as to cool a farm by the school of Civil, Urban and Geosystems Engineering at the Seoul National University, in Korea. Water flowing over or sprayed on the surface of a building reduces the cooling load in summer [Shin et al, 2000]. Mun and Han studied this effect on a farm thanks to a simple RWH system with an underground tank (heat transfer to the soil can be used besides for reducing the temperature of the recycled water) and with a rainwater cooling system (RCS) consisting in a circulation of water on the surface of the farm.

They assessed particularly:

* The effect of flowing water on the roof of the cattle shed using the rainwater cooling system, which was using the rainwater utilization facility equipped in the cattle shed as a cooling source

* The thermal regime of the rainwater tank installed underground.



Notes			
1	Catchment	Area	13 m X 14 m 9 m X 35 m
		Material	F.R.P
		Slope	17/100
2	Treatment		Filter (WFF150)
3	Rainwater tank		Polymer precoated steel tank (45 ton)
4	Pump		0.5 HP, Height 25m
5	Overflow pipe		D=100 mm

Figure 19 Process of the Rainwater Cooling System in a cattle shed

Rainwater was used for drinking water for 38 milking cows as well. It has been shown that when the RCS was operated for three hours in the afternoon (12:00 – 15:00), the average inside temperature of 27.9° C was lower than the average ambient 28.7℃ and inversely when the RCS was not operating. Concerning the underground tank, it has shown that a rainwater storage tank was able to be considered as a cooling source in the summer.

Further investigations using underground rainwater tank as means of cooling have been carried out. The project *Laboratory testing of a rainwater ground source heat pump* of the Institute of Building Technology at the University of Nottingham (UK) aims at developing a Ground Source Heat Pump (GSHP) system utilizing rainwater as a heat source/sink by employing two heat exchangers: the first for transferring heat between the heat pump and rainwater in the reservoir and the second for transferring heat between stored rainwater and surrounding soil.

5.3.2 Energy compensation in greenhouse

Within the frame of the Watergy project (see Appendix A), rainwater harvesting combined with a greywater recycling system and a greenhouse enable to obtain a water autarky building and a heat autarky building as well. Rainwater can be used for the irrigation of the greenhouse and have to be treated for indoor purposes.

The cleaning process works with different physical and biological principles. A filtration through a swamp bed can provide water useful for the greenhouse and/or to run a washing machine in a building for instance. A part of this water is used by the greenhouse for evapo-transpiration, thus recycling this water thanks to an air humidification and de-humidification process. The recycled water acquires a better hygienically quality than with the biological filtration and can therefore be used for cleaning and bathing or can be finally filtered to drinking water quality.

Beside the cleaning effect, a passive cooling is achieved. Evaporation has a twofold effect within the system and so acts as an interface between the water and the energy management [www.watergy.de].

5.4 Environmental impacts

Some researches have been investigated in order to evaluate the effective energy consequences of the implementation of a RWH system. In other words, the question is: is RWH set-up worthwhile when considering the overall environmental impacts in terms of mitigation of the climate change?

Mithraratne and Vale (28) introduced this consideration in their study *Rain tanks or reticulated water supply?* The implementation of RWH system can indeed cause environmental implications such as sustainable resource use, greenhouse gas emissions, etc.

They studied the life-cycle energy use, carbon emissions, and the cost of alternative water supply systems through three scenarios: use of mains supply only, use of rain tanks only to supply all domestic water demand for new developments in Greenfield sites lacking infrastructure and use of rain tanks to provide 65% of the domestic water demand for residential developments in already established areas. Rain tanks would provide water for toilet flushing, washing machine and garden watering, while reticulated supply would provide the balance.

The conclusions of this study were as follows:

- the current level of water consumption in Auckland (New Zealand) can not be sustained with rain tanks alone
- life-cycle energy, carbon emissions and costs depend on the rain tank material
- the practice of supplementing the mains supply with rain tanks increases the life-cycle energy and carbon emissions attributable to the water supply system of a house
- RWH systems with concrete tanks could be a method to reduce the energy use and cost associated with water supply to residential buildings in Auckland.
- The present study did not take into account stormwater management and waste water: for a true environmental evaluation it should be investigated.

That is the reason why some methodologies are developed in order to help decisions in implementing this kind of devices. The City of Melbourne provides a Framework for Delivering Climate Neutral Water Schemes consisting among other things in a greenhouse gas audit, a reduction of water use and an evaluation of sustainable water scheme.

However, it should be stressed that this theme of the R&D projects is actually a large aspect which should not be reduced to the greenhouse gas emission. It should indeed also take into account for instance the water cycle scheme (emissions in surface and groundwater) and not only the atmospheric emissions. The environmental impacts are a complex field of investigation and for the moment only greenhouse gas emissions and life cycle of RWH systems are really investigated [*Mithraratne and Vale*, (28)].

5.5 Economical aspects

It is obvious that economical aspects have to be drivers in RWH set-up to enable the expansion of this water management. According to Leist (2007, (29)) the utilization of rainwater in households in parallel to an existent drinking water supply results in increased material and energy consumption and therefore does not have an economic benefit. Reasonable applications in terms of economic benefit may be found in industry, when serving larger buildings or in water scarce regions, where we will find different boundary conditions and needs.

Some decision-making tools have been implemented for this purpose. The Maubeuge Construction Automobile project uses evaluation software of the technical and economic profitability of rainwater on an industrial site (SIRRUS) in order to assess the potential investment of such installation [*Le Pol et al, 2000, (27)*]. This tool can be used for other similar projects to help decision in implementing a RWH system and to evaluate the economical feasibility of such project.

There is indeed a need to develop concepts which are economically feasible and viable, but this will highly depend of the local context (price of water, rainfall patterns, water resource, demography, etc.). Appropriate design and decision tools could help developing technically and economically optimised scenarios of RWH systems.

5.6 Integration of Stormwater Management and Rainwater Harvesting

Stormwater management consists mainly of the reduction and retention of peak runoff for combined sewers system and of the stormwater runoff pollutant load for separate sewers system. It implies to make easier rainwater infiltration by infiltration trenches, grassed swales, vegetated filter strips and in so doing to mitigate the impacts that urbanization normally has on the water balance [Ministry of the Environment, Ontario, 2003].

RWH can reduce load pollutants and avoid soil clogging (resulting in an infiltration less efficient), thus improving stormwater management. And on the other hand, stormwater management by retaining nutrients and heavy metals improves water quality as well.

It appears as a consequence that these both aspects could be combined in order to be more efficient in an overall urban water management. However, the optimisation of such integration will depend on the type of sewers (combined or separate) among others.

The most common practice integrating a stormwater management and a RWH system is the installation of green roofs, as stated previously (see Chapter 3, section 3.1.2.), but green roofs have shown their boundaries in case of strong runoffs, releasing rainwater. It would be then a necessity to develop and carry out other possibilities for the combination of these both aspects.

When considering the listed R&D projects (see Appendix A), it seems to be a lack of investigations in that field. Many projects deal with either Rainwater Harvesting or stormwater management but only a few of them combined the two approaches: managing stormwater and then reusing the stored rainwater.

Germany, with the Potsdamer Platz project and the Institute of Physics (see Chapter 4), has carried out investigations concerning the optimisation of both aspects. Australia shows advances in that field. As example, the project Manly Stormwater Treatment and Re-use (STAR), in Sydney, uses the stormwater of a 3 ha catchment area (in a developed ultra-urban suburb with a high population density) for irrigation. The treatment used consists of permeable pavements, coarse and fine screens, and filtration through ecosoils to underground storage tanks where final sedimentation occurs. In this project, while stormwater is used for irrigation, infiltration of runoff to groundwater is facilitated as well.

Australia is leading this R&D aspect with its Water Sensitive Urban Design (WSUD).According to Mitchell et al. (2007, (30)), the integration of stormwater reuse into WSUD approaches provides a method to achieve multi-purposes outcomes such as potable water supply substitution, protection of surface waters from stormwater flow and pollution, and enhanced aesthetics of the urban environment. As a matter of fact, an integrated urban stormwater reuse system should provide five core functions: collection, treatment, storage, flood and environmental flow protection and distribution to end users.

As for the other R&D needs, it is obvious that there is a real need in terms of knowledge, decision and management tools to optimise the integration between rainwater harvesting and stormwater management.

Chapter 6
Conclusion

Climate change, water scarcity issues, flood management, this global background encourages authorities to find out alternative solutions for their water management and to integrate them in their urban design. Rainwater harvesting (RWH) is one of the sustainable answers of these issues, which becomes more widespread worldwide, in spite of some divergences within the scientific community concerning hygienic aspects (not focused of this review).

The state of the art of RWH has highlighted some discrepancies between countries: between developed and developing countries whose RWH purposes are different (principally water savings and drinking water supply), and gaps within developed countries themselves as well. Concerning these developed countries, distinctions according the acceptance and the standards of this concept and regarding the complexity of implemented projects have been reported. Relevant projects are detailed in the fact sheets of the Chapter 4.

The different scales of application can be discussed. It appears that for households, technologies are at the end of their development and well known whereas there is more potential to develop systems at a large scale (for large buildings and urban stormwater runoff harvesting). In other words, the less important the scale of applications, the more well known and the more achieved technologies (low-tech); and on the other hand, the more important the scale, the less return on experience and the more possibilities of technological development and challenges there are (high-tech).

This report lists the main guidelines concerning RWH and which are essentially implemented in Germany and in Australia.

Recent R&D projects deal with six main aspects (including sanitary aspects). The first concerns drinking water. This aspect is maybe one of the most controversial prospects for

RWH since there is no consensus concerning rainwater quality and that the acceptance is highly country-dependant. But Australia is leading the investigations in that way and the return on experiences could enhance other countries to follow this concept.

In terms of energy compensation, rainwater is often used to cool buildings instead of using traditional air-conditioning systems and this use has already proved its efficiency through several projects such as at the Institute for Physics (Berlin). Other concepts for water autarky building usually combined with greenhouse use evapo-transpiration process in order to cool as well buildings.

Environmental impacts are in addition investigated in order so far to assess mainly the carbon footprint generated by a RWH implementation, but research environmental impact assessment of RWH schemes should also include issues such as climate change mitigation and non atmospheric pollution emissions (surface and groundwater).

The economical aspects are studied as well with generally the intention to produce decision tools for the set-up of such systems. However, economical investigations, like the studies on environmental impact, are very complex and the current investigations are far from being comprehensive.

Finally, the integration of stormwater management and rainwater harvesting which could be one of the most comprehensive rainwater management is unfortunately not a common aspect in the R&D projects. They indeed deal with either one or the other aspect but the association of the both is quite rarely performed. Investigations concerning this integration should be further developed.

More generally a need of knowledge decision and management tools was noted throughout the current R&D orientations on Rainwater Harvesting.

To conclude, it is obvious that whatever the progress of RWH systems, a larger implementation of such technologies in given countries will always require a legal and political support from the local authorities.

Appendix A

List of R&D projects

Name	Instrument	Date/ Duration	Project origin location	Case study location	Description			Contacts Reference
					General points	Use of Rainwater	Other alternative water sources	
ClimateWater	FP7-Project	Not officially launched yet	Europe		Analyse and synthesise data and information on the likely water-related impacts of the climate changes. Identify and quantify how the currently existing and planned European water-related policies take the likeliness and magnitude of water-impacts and the urgency of adaptation into account.			info@climatewater.org www.climatewater.org
Switch	FP6-Project	2006-2011	Europe	Africa, South-America, Europe	Achieve a sustainable, healthy and safe urban water system, through a paradigm shift in water management. Stormwater management, rainwater harvesting.			www.switchurbanwater.eu
Cycler Support	FP6-Project		Europe	Mediterranean countries	waste water use and recycling by using new generation greenhouse systems	effective possibilities of rainwater harvesting from the roof	Sea water	www.cycler-support.net
AquaStress Work Package 3.1	FP6-Project		Europe Project partners: IRD (France) University of Exeter (UK)	Merguellil, Kairouan region, Tunisia	Results of modelling RWH at the test site to provide a tool for appropriate management of the whole water system in the catchment basin with different scenarios considered, based on different uses of water: agriculture, tourism, drinking.			www.aquastress.net alfieri.pollice@ba.irsa.cnr.it
Watergy A novel solar humid-air-collector system for combined water treatment, space cooling and heating.	FP5-Project	2003/ 2006	Europe	Europe	Platform for decentralised basic supply of energy, water and food that can be used within a number of different applications. Closed greenhouse without external aeration and almost no need for further water supply. Heat- and water autarky buildings: greenhouse, rainwater harvesting		Graywater reuse, Desalination	www.watergy.de
Aquifer Storage Recovery ASR Parafield				Parafield, Australia	Stromwater injected through a well in an aquifer afte being filtered through a wetland and recovered through the same well for irrigation.			www.smartwater.com.au

Name	Instrument	Date/ Duration	Project origin location	Case study location	Description			Contacts Reference
					General points	Use of Rainwater	Other alternative water sources	
Reclaim Water ASTR Salisbury	FP6-Project	2005-2008	Europe	Adelaide, Salisbury, South-Australia	Wetland treated urban stormwater injected into a brackish aquifer. Water recovered via separate recovery wells. Six well systems in operation. No chlorination. Recovered water intended for drinking supplies, and until proven will be used for irrigation.			http://www.clw.csiro.au/research/urban/reuse/projects/astr-salisbury.html
Gabardine	FP6-Project		Europe Germany, Göttingen	Portugal Algarve test site at Campina de Faro	Use the surplus surface water from a small river basin. Store surface water surplus through aquifer recharge with infiltration ponds to improve groundwater quality (nitrate problem)			www.gabardine-fp6.org
Preventing pollution and saving water resources by reuse of industrial rainwater	EU-Life	1997-2000	Europe France	France	Demonstration of the technical feasibility and profitability of reusing industrial rainwater for industrial processes. Realisation of a stormwater reuse system on a demonstration site of the car industry			jean-sebastien.thomas@generale-des-eaux.net
Vital Vaasa – Pilot framework and action programme for revitalisation of the water cycle in an urban landscape structure	EU-Life	1999-2002	Europe Finland	Vaasa, Finland	Test and develop methods for the restoration of rainwater circulation in a city area.	Develop cleaning methods for rainwater as well as ecological methods for using the rainwater.		www.vaasa.fi/vitalvaasa/
Flash Floods in Egypt: protection and management	EU-Life	2007-2009	Europe	Egypt	Achieve a sustainable management of water resources in the Sinai Peninsula	Wise use of floodwater for the sustainable management of water resources. Improvement of water storage and facilities.		www.flaflom.org

Name	Instrument	Date/ Duration	Project origin location	Case study location/ Beneficiary countries	Description			Contacts Reference
					General points	Use of Rainwater	Other alternative water sources	
Groundwater suppletion through rainwater and treatment of overflow water by a helophyte filter	EU-Life	2001-2004	Europe, Netherlands	Winterswijk Netherlands	Network to collect surface water and infiltrate it into dry built-up areas. Retention and infiltration facilities are being put in place for the collection of excess water.	Work with households to establish possibilities for separately collecting rainwater.		www.winterswijk.nl
Optimizagua: demonstration of water saving in watering uses through experimentation with artificial intelligence models combined with traditional water control systems and rainwater storage tanks.	EU-Life	2003-2006	Europe	3 demonstration corps: 1- CORN, Garray, Spain 2- WHEAT, Monte Julia Estate, Chile 3- LAWN GRASS, Parque Oliver Zaragoza, Spain	Combine traditional rainwater harvesting systems with water controls systems where possible, depending on the characteristics of the zone and the terrain.			www.life-optimizagua.org
Zer0-M: sustainable concepts towards a zero outflow municipality	Meda Water Program	2003-2008	Europe	Egypt, Morocco, Tunisia and Turkey	Concepts and technologies to achieve optimised close-loop usage of all water flows in small municipalities or settlements not connected to a central wastewater treatment.		Grey and black water reuse	www.zer0-m.org

Name	Instrument	Date/ Duration	Project origin location	Case study location/ Beneficiary countries	Description			Contacts Reference
					General points	Use of Rainwater	Other alternative water sources	
AKWA 2100: Alternativen der kommunalen Wasserversorgung und Abwasserentsorgung (alternatives to the municipal water supply and sewage disposal system)	Pilot project of the WestLB-Foundation "Future of North Rhine-Westphalia"	2000	Europe, Germany	Dortmund-Asseln, Selm-Bork, Germany	Sustainable rearrangement of municipal water supply and sewage disposal: create cycles fort he re-use of water and its usable contents, integrate resource-saving and maintenance friendly technologies. Use of different scenarios of alternative urban water infrastructure systems including collection of waste water streams (rainwater), treating the waste water and the reuse.			
DEUS 21: Decentralised Urban Infrastructure System	German Federal Ministry for Education and research BMBF	2004	Europe, Germany	Knittlingen, Germany	Municipal water management (100 housing plots).	Rainwater collected and lead to the households via a separate service water network.		www.deus21.de
BNWAT 19: Alternative sources of water – greywater and rainwater reuse	Defra's Market Transformation Programme	2006	Europe, UK	United Kingdom	Goals: using rainwater for garden watering, toilet flushing and washing machines. Support different types of rainwater harvesting (cleaning, process water, irrigation…)		Greywater, reclaimed water	www.mtprog.com
Homebush Bay	Australian Water Conservation and Reuse Research Program	1999	Australia	Sydney, Australia	Encourage development of innovative and effective wastewater treatment technologies and management practices. Reuse for irrigation, water features and other outdoor uses, toilet flushing, fire fighting.			
Figtree Place	Australian Water Conservation and Reuse Research Program	1995	Australia	Hamilton, Newcastle, Australia	Retain stormwater on-site and reduce potable water consumption	Garden and open space irrigation, bus washing at adjacent depot, other outdoor use		
Oaklands Park	Australian Water Conservation and Reuse Research Program	1997	Australia	Melbourne, Australia	Best practice approaches to ecologically sustainable design	Runoff distributed via mains pressure reticulation system and reused for non potable purposes, fire fighting etc.		

Name	Instrument	Date/ Duration	Project origin location	Case study location/ Beneficiary countries	Description			Contacts Reference
					General points	Use of Rainwater	Other alternative water sources	
Simple rainwater cooling system for the cattle shed roof on a dairy farm	The school of Civil, Urban & Geosystems Engineering		Korea	Seoul National University, Korea	Rainwater considered as both a cooling and heating source as well as a part of the restoration of a sustainable water cycle. Rainwater cooling system used for cooling the cattle shed on a dairy farm in hot weather.			
Sustainable drainage in Peking		2000	Partnership between the Beijing Hydraulic Research Institute and BMBF (Bundesministerium für Bildung und Forschung)	Peking (Haidian District)	Demonstration and Research installation in a 120 inhabitants building. Infiltration, control of the discharge, water-saving measures, combination of greywater recycling and rainwater use.		Greywater recycling	Fbr-wasserspiegel März 2003 http://fbr.de/fbrwasserspiegel.html
Temasek Polytechnic			Singapore	Singapore	Storage of rainwater in 4 underground tanks. Around 8000 m^3 per months of non potable water used for floor washing and irrigation. Water treated by ozonation.			n.voulvoulis@imperial.ac.uk

Appendix B

Firms and contacts

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Rainwater: planning, technic and installation

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Appendix C

Rainwater Networks

country	organization	address	Fax	Email Website
Australia	Public and Environmental Health Service	Dept. of Human Services, P.O. Box 6, Rundle Mall, SA 5000, Australia	8226 7102	ehb@health.sa.gov.au
	SA WATER (South Australian Water Corporation)	GPO Box 1751, Adelaide, SA 5001	8-8359 2567	marilla.barnes@sawater.sa.gov.au
Canada	DALTECH (Centre for Water Resources Studies)	Centre Water Resources Studies, Dal Tech, Dalhousie University, PO Box 1000, Halifax, Nova Scotia, Canada B3J 2X4.		scottrs@newton.ccs.tuns.ca
	IDRC (International Development Research Centre)	P.O. Box 8500	613-238 7230	info@idrc.ca www.idrc.ca
Germany	FAKT (Association for Appropriate technologies)	Gunsheidstrase 43, D-70184, Stuttgart, Germany	711-210 9555	100557.3651@compuserve.com
	fbr (Fachveeninigung fur Betriebs und Regenwassernutzung e.v)	Specialist Association for Rainwater Utilization Kasseler Str. 1a, D-60486, Frankfurt am Main, Germany	69-9707 4648	www.fbr.de info@fbr.de
	WISY (Winkler Systems)	OT Hitzkirchen, Oberdorfstrasse 26, D-63699,	54-912129	wisyag@t-online.de

		Kefendrod-Hitzkirchen Germany		
India	CSE(Centre for Science and Environment)	41, Tughlakabad Institutional Area, New Delhi, 110 062, India	11-698 5879	cse@sdalt.ernet.in www.cseindia.org
	The Ajit Foundation	396 Vasundhara Colony, Tonk Road, Jaipur 302 018, India	141-519938	visquar@jp1.vsnl.net.in
Kenya	ASAL Consultants Ltd.	P.O. Box 38, Kibwezi, Kenya	_2-740524	ccatsarit@net.2000.ke.com
	KRA (Kenya Rainwater Association)	P.O. Box 72837	_2-560438	gscons@arcc.or.ke
	RAINDROP (Published by the Rainwater Harvesting Information Service)	P.O.Box 38638, Nairobi, Kenya	_ 2 556943	bambrah@AfricaOnline.co.ke
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	Partnership)	105 25, Stockholm, Sweden	5627	www.gwp.sida.se
	SIDA (Swedish International Development Agency)	S-105 25 Stockholm, Sweden	8-698 5653 / 208864	ingvar.andersson@sida.se www.sida.se
Thailand	IFIC (International Ferrocement Information Centre)	Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand	2-516-2126	geoferro@.ait.ac.th
	Khon Kaen University	Water Resources and Environment Institute, Faculty of Engineering, P.O. Box 26, Khon Kaen University, Khon Kaen 40002, Thailand	43-237 604	
	PDA (Population and Community Development Association)	8 Sukhumvit 12, Bangkok 10110, Thailand	2-2558804	
UK	DTU (Development Technology Unit)	Engineering Dept, Warwick University, Coventry CV4 7AL, UK	1203-418922	dtu@eng.warwick.ac.uk
	IT Publications (Intermediate Technology Publications)	103-105 Southampton Row, London, WC1B 4HH, UK	171-436 2013	journals.edit@itpubs.org.uk www.oneworld.org/itdg/
	WaterAid	Prince Consort House, 27-29, Albert Embankment, London SE1 7UB, UK	171 793 4545	wateraid@compuserve.com www.oneworld.org.wateraid

	UKRHA (UK Rainwater Harvesting Association)			www.ukrha.org
	WEDC (Water, Engineering and Development Centre)	Loughborough University, Loughborough, LE11 3TU, UK	1509 211079	wedc@lboro.ac.uk www.lboro.ac.uk/departments/cv/wedc/
USA	University of Texas			
	IWRA (International Water Resources Association)	4535 Faner Hall, Southern Illinois University, Carbondale, IL 62901-4516, USA	505-277-9405	iwra@siu.edu www.iwra.siu.edu
	UNDP World Bank Water and Sanitation Program	The World Bank, 1818 H Street, NW, Washington, DC 20433 USA	202-522-3313	info@wsp.org www.wsp.org
	VITA (Volunteers in Technical Assistance)	1600 Wilson Boulevard, Suite 500, Arlington, VA 22209, USA	703 243 5639	vita@vita.org
	Water Resources Research Centre	University of Hawaii at Manoa, 2540 Dole St, Homes Hall 283, Honolulu, Hawaii 96822, USA	808-956-5044	
international institution	UNICEF	UNICEF House, 3 United Nations Plaza New York, New York 10017 USA	(212) 888-7465	netmaster@unicef.org www.unicef.org
	IRCSA (Int. Rainwater Catchment Systems Association)			orojessie@yahoo.com www.ircsa.org/

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8th International Rainwater Catchment Systems Conference (1997)	Jamal Ghoddousi / Bahram Aminipouri, SCWM Research Centre, P.O. Box 13445-1136, Tehran, Iran
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7th International Rainwater Catchment Systems Conference (1995)	Changming Liu, CAS, Bldg 917, Datun Rd, Beijing 100101, China
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6th International Rainwater Catchment Systems Conference (1993)	G.K. Bambrah P.O.Box 38638, Nairobi, Kenya
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Conference on Fog and Fog Collection (1998)	P.O.Box 81541, 1057 Steeles Avenue West, North York, Ontario, M2R 2X1, Canada
	Fax: 416-739-4211
	Email: fogsite@ibm.net
	Website: www.tor.ec.gc.ca/armp/Events.html
National Conference on Rainwater Harvesting (1998)	CSE (Centre for Science and Environment) 41, Tughlakabad Institutional Area, New Delhi, 110 062, India
	Fax: 11-698 5879

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	Website: www.cseindia.org
Tokyo International Rainwater Utilization Conference (1994)	Makoto Murase, Dept. of Environmental Protection, 23-20 Azumabashi-1-chome, Sumida City, Tokyo, Japan
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