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Rainwater harvesting for stormwater management: example-based typology and current approaches for evaluation to question French practices

L'intégration de l'utilisation de l'eau de pluie dans la gestion des eaux pluviales : enjeux, typologie d'approches et évaluation

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ABSTRACT

Rainwater harvesting (RWH) practices have known a revival of interest in France since 2008. This revival of interest is taking place in a context where, in France like in many other countries, local policies requiring source control measures for stormwater (SW) management are becoming more and more developed. This context leads to reconsider the role that can be played by RWH for SW management. In this respect, foreign experiences can prove beneficial. Hence, an exploratory study was launched to a) identify and analyse several projects and local policies considering RWH for SW management abroad, and possibly in France, in order to build typologies, b) review scientific work available on the evaluation of the benefits of RWH for SW management, at different scales and c) draw conclusions to compare French practices and international approaches.

RÉSUMÉ

Les pratiques de récupération et utilisation de l'eau de pluie (RUPE) ont connu un renouveau en France depuis 2006. Ce renouveau intervient dans un contexte de renforcement des politiques de gestion à la source des eaux pluviales (infiltration, rétention) et invite donc à questionner le rôle que les pratiques de RUPE peuvent y jouer, à l'image de réflexions menées dans d'autres pays. Pour accompagner l'évolution des pratiques françaises, une étude bibliographique s'est ainsi attachée à a) identifier et analyser à l'international, et le cas échéant en France, différents projets d'aménagement et politiques locales prenant en compte l'utilisation de l'eau de pluie pour la gestion des eaux pluviales, en vue de la construction d'une typologie d'approches, b) synthétiser les travaux disponibles dans le domaine de l'évaluation des bénéfices apportés par la mise en oeuvre de dispositifs d'utilisation de l'eau de pluie pour la gestion des eaux pluviales, à différentes échelles et c) dégager des éléments de synthèse, mettant en perspective pratiques internationales et pratiques françaises.

KEYWORDS

Design, Evaluation, Local policies, Rainwater harvesting, Sizing, Stormwater management

INTRODUCTION

In France, rainwater harvesting (RWH) has known a revival of interest since the establishment in 2006 of a national tax credit for households implementing a rainwater collection system. This tax credit came up with the new Water Act (*Loi sur l'Eau et les Milieux Aquatiques*). Some regulations have then been defined to better manage the use of rainwater and to precise the technical requirements to be met by the components of the collection systems supplying both outdoor and indoor uses (JORF, 2008). Although the French market is not mature yet, and remains less advanced compared to countries like Germany in Europe, rainwater harvesting tends to develop or, at least, to be considered in a more regular way in construction projects.

This renewed interest is taking place in a context where local policies requiring source control measures for stormwater (SW) management are becoming more and more developed (infiltration, retention) and this leads to reconsider the role that can be played by RWH for SW management. Indeed, RWH traditionally relates to water saving and protection issues (UNEP, 2009; de Gouvello et al., 2013), but not with SW management. This trend is particularly true in France where, contrary to other countries discussed later on, there are few examples for which RWH is being promoted in order to reduce SW discharges into water bodies and sewer networks.

Analysis of foreign experiences can thus prove beneficial to question French practices. In this respect, an exploratory study from the scientific network of the French Department of the Environment was launched to precise issues associated with the consideration of RWH for SW management (1), identify and analyse several projects and local policies considering RWH for SW management (2) and make a short review of scientific work available on the evaluation of the benefits provided by rainwater collection systems for SW management (3) (Gerolin, 2012).

1 CONTEXT: WHY CONSIDERING RAINWATER HARVESTING FOR STORMWATER MANAGEMENT?

1.1 Ways to associate RWH and SW management practices

In urban water management, the usual sector-silo approach (potable water, wastewater, stormwater, rainwater, process water, ...) do not promote integrated approaches. Water saving issues are a good example to understand the importance of taking several urban water sectors into account during the planning process. So do stormwater (SW) management issues.

Indeed, SW management has long been considered separately from other water issues and water sectors. This way of doing showed its limits (floods, pollution to the water bodies, increasing costs) and led to the development of source control policies and measures (infiltration, retention, detention,...) in different countries, among which France (MEDDE, 2012).

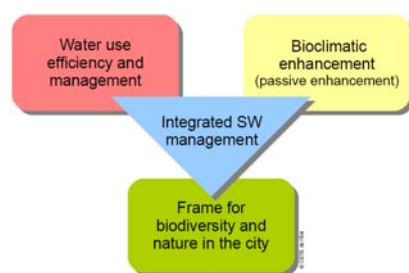


Figure 1 – Urban stormwater (SW) management and its interactions

These evolutions have to be continued and urge to consider more widely the interactions between SW management and other urban water management issues, such as presented on Figure 1.

Regarding France, the connection between SW management and water use efficiency is promoted by the renewed interest for rainwater harvesting (RWH) for outdoor and indoor uses that do not require potable water. RWH has gained greater recognition since 2006 following the establishment of a first national regulatory framework: establishment of a national tax credit, issue of a dedicated Order in 2008 (JORF, 2008).

Despite that, in France, RWH still remains strongly associated with water saving and protection issues rather than SW management issues. However, a slight evolution becomes apparent. Since 2009, some River Basin Management Plans - planning documents defined by the EU Water Framework Directive - has considered RWH within their content as one way to tackle SW management issues. At a smaller scale, some municipalities, or inter-municipalities groups, provide RWH incentives for households in order to reduce SW discharges in watercourses and/or sewer networks (towns such as Aix-les-Bains, Chassieu, Communauté d'Agglomération du Grand Montauban, ...).

More, the French Government recently gave the right to local municipalities, or inter-municipalities groups, to implement an area-based stormwater management tax (MEDDE, 2012). This rises in a more explicit way the question of the position of rainwater collection systems among source control

measures. Indeed, according to the national regulatory framework defined for this tax, the owners liable to the tax can benefit from a credit if they install a rainwater tank. This credit cannot be higher than 40% and its value is at the discretion of municipalities.

1.2 Questions arising from the field

This topical area-based stormwater management tax – defined at the national level - actually rises the question of the connection between source control measures (swales, trenches, retention basins, ...) and rainwater collection systems. At first sight, the incompatibility between the objectives linked to SW management – which suppose at each time an available storage volume to cope with a rainfall event – and those associated with the satisfaction of the uses supplied by rainwater - which suppose some water continuously available in the tank - led in France to the exclusion of RWH from the reflections on SW management, for want of a cautious approach (Conseil Général de Seine-Saint-Denis, 2009; de Gouvello, 2010). A closer look shows that rainwater collection systems and source control measures are designed to respectively provide a number of well-defined functions. These functions are reminded on Figure 2.

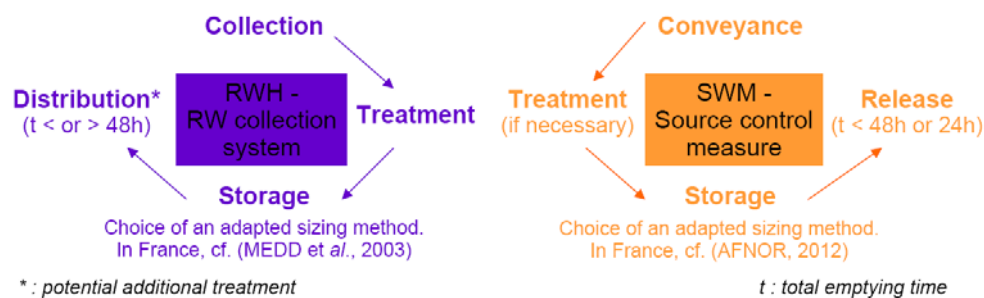


Figure 2 – Simplified functional approach for rainwater collection systems and stormwater management measures

On Figure 2, some functions can appear to be similar. This is the case for the *Storage* functions; however, the latter rely on different rationales (for instance, it is interesting to maximize the collection area to increase the yield of a rainwater tank whereas it is interesting to reduce this same area to limit soil imperviousness) and different sizing methods. The *Release* and *Distribution* functions also appear to be similar; however, they rely on different requirements, namely a quick emptying time for source control measures – to cope with another rainfall event – or a longer emptying time to maximize the yield of rainwater collection systems supplying outdoor and/or indoor uses.

So, although being designed and sized to manage distinct objectives, a distortion is sometimes made to assimilate rainwater collection systems and source control measures. This possibility, by way of some adaptations, is not senseless from a technical point of view. Some authors also put forward an economic factor, in particular for large scales (König, 2010). The question is to know whether the combined cost associated with a rainwater collection system can be reduced by a better incorporation as a component of the SW management system (Reidy, 2008), considering also the future operation and maintenance costs (Liaw et al., 2007). The idea is thus to avoid a would-be expenses prioritization in building constructions since the sole costs for source control measures – which tend to become inevitable – can restrain an additional investment for RWH (Forasté et al., 2010). Thus, the technical and economical interests of a better articulation between RWH and SW management do not result today in a common approved argumentation.

To go over these observations on the limitations of RWH for SW management and to further question French practices, the analysis of foreign experiences is a first step that can be useful.

2 RAINWATER HARVESTING ASSOCIATED WITH STORMWATER MANAGEMENT: EXAMPLES AND PLANNING SCALES

2.1 Considerations in the design of construction developments

2.1.1 Design principles for lot scale developments

Lot scale developments are a gate for the identification of technical solutions merging source control and rainwater harvesting. On one hand, solutions can consist of all-inclusive systems such as shared tanks (harvesting volume / detention volume). On the other hand, they can consist of an infiltration of the overflow of rainwater tanks. Sales literature is numerous.

Some design adaptations - fitting for instance to high-density areas - can also be found. For Instance, a system developed in Germany includes a porous concrete ring in the upper part of a rainwater tank to ensure the infiltration of the overflow around the tank (König, 2010). Another system, tested in Australia, allows storing rainwater directly into the gutter to supply gravity-fed uses; the overflow is then connected to pervious areas around the house (Hardie, 2010). Other design adaptations rely on the maximization of the drawdown of rainwater collection systems (Reidy, 2008; Maryland DE, 2009; Forasté et al., 2010).

These adaptations can be applied to collective buildings. As for the Institute of Physics of the University of Berlin, the overflow of the tank – for the watering of green façades and the supply of the central air-conditioning system – is connected to a small constructed pond (Schmidt, 2009). As for the Star City building in Seoul, it includes a real-time control system to manage the volumes of water in a 3.000 m³-shared tank; each part of the shared tank addresses a given objective: flood control, water saving, fire-fighting (Han et al., 2011).

Some examples have been identified in France (Noeuvéglise et al., 2007; Conseil Général Seine-Saint-Denis, 2007) but appear to be rare. As for the *Grand Pigeon* school in the town of Angers, the system relies on the installation of two related tanks, instead of two independent ones (Manent, 2010).

2.1.2 Design principles leading to a general implementation or a sharing of components

The previous design principles can lead to a general implementation in residential areas. As for the *Hohlgrabenäcker* area of Stuttgart-Zazenhausen (17 ha) in Germany, 56 rainwater tanks whose overflows are connected to local infiltration areas take part in the SW management drainage system, also including green roofs and porous areas (König, 2010): planning at a larger scale has thus enabled to influence the definition of the SW management system of the project. In France, the implementation of shared tanks in housing estates is said to be on the rise in the East of the country, maybe because of the proximity with Germany and Belgium. As for the district of *Rue du Lac* in the town of Lingolsheim, the overflows of the rainwater tanks are directed towards a swale behind the housings for the watering of a planted area.

In a different manner, some projects identified are built on principles that cannot be applied on a single lot. For these cases, considering the immediate environment of the project can account for a sharing of some of its components during the design process:

- sharing of the collection areas in order to improve the yield of the rainwater collection system : as for the *Tour Sequoia* in the town of Issy-les-Moulineaux near Paris, rainwater is collected from the roof of the tower but also from close buildings; the overflow of the tank is connected to a stormwater detention basin (Manent, 2010) ;
- sharing of the overflows of rainwater tanks for a common infiltration (König, 2001) or a contribution for the urban environment enhancement (König, 2001; Atelier Dreiseitl et al., 2008). In France, the urban development *ZAC de Rungis* in Paris, under construction, looks experimental: the design process took into account some pre-existing drainage infrastructures to store the overflows of the tanks located within the project area; the stored water will then be used for public spaces watering or will be infiltrated when in excess.

2.1.3 Factorisation into a design typology

The projects identified helped find some recurrent design principles, likely to be made more complex at larger scales. On the opposite, it has been shown before that some principles used at a given scale cannot be applied at a smaller one. A simplified design typology of cases where rainwater tanks are integrated to source control measures is thus proposed in Table 1 and can be used as part of this study to create – for instance - a common language between practitioners.

It is interesting to note that several projects, in France and abroad, are designed to avoid – and not only to limit – stormwater discharges into watercourses or sewer networks, when the local context allows for it (infiltration, ...).

Table 1 – Simplified design typology for the integration of rainwater collection systems (RWH) into source control measures for SW management (SWM)

	Case 1 – No adaptation	Case 2 – RWH and SWM put in parallel	Case 3 – RWH and SWM put in series	Case 4 – RWH and SWM with real-time control
Lot scale development				
	The storage volume that may be available in the rainwater tank before a rainfall event ensures alone stormwater management. This case includes no design adaptation.	A storage volume on top of a rainwater tank, coupled with an intermediate throttle rate, ensures stormwater management. The throttle rate (<i>release</i>) is also the overflow of the tank.	The management of the overflow of the rainwater tank into an infiltration or a retention/detention measure – in series or incorporating the tank – ensures stormwater management.	The real-time management of the volumes of water contained in a unique rainwater tank (passive or active drawdown according to the needs) ensures stormwater management.
Urban project scale	For urban projects, residential areas, housing estates, etc.: - a general implementation of one or several design principle(s) (cases 1 to 4) is possible, - a sharing of the collection areas and/or the rainwater tank (RWH) and/or the overflows of several rainwater tanks (RWH) is possible.			

* Potential overflow of the source control measure (SWM). Its implementation is not systematic.

The typology of Table 1 only considers the integration of RWH in SW management on the basis of construction developments. It can be useful to emphasize points to pay particular attention to during design, sizing, installation, operation and maintenance - not detailed in this paper. However, the existing literature shows that the consideration of such integration can also arise during the definition of local policies for SW management, as detailed below.

2.2 Considerations during the definition of local policies for stormwater management

2.2.1 Experiment and model-based approaches

The examples that have been studied are mainly identified out of France. They appear to be quite experimental, such as the approach developed in the State of Virginia in the United-States. This initiative is part from a project aiming at reducing pollution across the watershed of the Chesapeake Bay (Figure 3). Stormwater runoff is identified as being one of the major sources of pollution.

Considering that the limitation of peak flows was not necessarily the best strategy to protect the Bay - increase in the number of current floods, no reduction of SW discharge volumes – the State of Virginia updated its local SW management policy in a way to address the volume of runoff generated during rainfall events. Since the local specifications have then been based on the analysis of the overflow volume and frequency of the SW management system, it could practically account for the benefits provided by RWH.

To do so, an evaluation methodology was developed and a sizing tool (spreadsheets) created for the attention of practitioners. With this tool, the overflow frequency of rainwater tanks can be estimated regarding the collection area, the uses of rainwater and the localisation. According to the results, practitioners know whether a design adaptation of the tank has to be made, such as shared tanks (Forasté et al., 2010). Since then, this decision-making tool has been introduced in the RWH technical guidance from the State of Virginia (Virginia DCR, 2010).

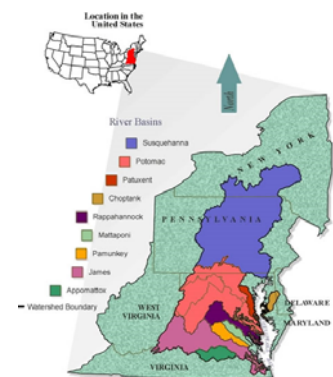


Figure 3 – Watershed of the Chesapeake Bay (University of Virginia)

The initiative of the State of Virginia seems like a pioneer initiative in the US. It seems to spread over other States of the watershed of the Chesapeake Bay. For instance, in North Carolina, the Department in charge of Environment has defined a local policy to grant credits on the roof area to be considered for the calculation of storage volumes in compliance with SW management requirements (North Carolina DENR, 2008).

Flood prevention can also be addressed. This is the case on the River Parramatta watershed (130 km²), in the South-West of Australia, where water quality and flooding issues are sensitive. As part of the definition of a local SW management policy, a prospective work has been carried out at the watershed scale – with academic support (Coombes et al., 2001) – to define tools to account for the quantitative benefits of rainwater tanks. Again, the practical tools rely on the allowance of credits. In this case, credit means the proportion of the volume of a rainwater tank that can be considered as providing storage for effective runoff control during a rainfall event. This theoretical available storage volume can be deducted from the required storage volumes for SW management in order not to aggravate pre-development flows. The methodology has been introduced in the local SW management technical guidance (UPRCT, 2005).

Other examples where credits are allowed can be found in the implementation of SW management fees, well before the French Government gave municipalities the right to do so. Examples can be found in German towns, such as Karlsruhe. In Berlin, a fixed deduction of 10% is granted for the collection area to be taken into account for the sizing of the SW management system if the overflow of the rainwater tank is connected to the sewer, or greater if it is not (Durand, 2011).

The aim of a local SW management policy considering RWH can also be to promote – in different ways – a more general implementation of the design principles summarized in Table 1. Instructive examples can be found in countries from South-East Asia. Following severe floodings, which occurred in Seoul city in 2001, and some economic considerations, researchers have turned to the development of decentralized SW management systems and, among them, rainwater collection systems. The city of Seoul started in 2005 an incentive policy for the promotion of RWH practices (Kim et al., 2007). Experimental projects based on a general implementation of tanks with real-time control devices are investigated (Han et al., 2007). The idea of turning to real-time control can also be found in Hanoi (Anh-Dzung et al., 2009) and on the Hii River watershed in Japan (Moriyama et al., 2012).

At least, promoting a general implementation of adapted design principles can more simply consist in allowing subsidies for technical solutions such as those presented in Table 1 (Han et al., 2007; Shuster et al., 2010). As for the experimental project *Little Stringybark Creek* (2007-2013) aiming at encouraging the inhabitants of a district of Melbourne city to disconnect their SW discharges from the nearby watercourse, auctions have been set up for the purchase of rainwater tanks or raingardens (Fletcher et al., 2010).

2.2.2 Different levers for decision-makers

The local policies identified show that the integration of RWH can occur at different scales: district, town, watershed, State. The implementation of such policies can also take place under various forms. The tools adopted by decision-makers are various, and likely to be used in association:

- **local regulations**, making rainwater harvesting mandatory (Kim et al., 2007; Gabe et al., 2012) or defining requirements for its integration during the global design process (North Carolina DENR, 2008; ACT Planning and Land Authority, 2009; Maryland DE, 2009) ;
- **technical prescriptions** established by an institutional actor, i.e. prescriptions for the integration of rainwater tanks during the sizing process of the SW drainage system (Virginia DCR, 2010 and Forasté et al., 2010 ; UPRCT, 2005 ; New-York DEC, 2010) ;
- **financial incentives** for the purchase of rainwater tanks (Han et al., 2007; Fletcher et al., 2010; Shuster et al., 2010) or for the allowance of credits when local SW management fees have been set up (Durand, 2011; MEDDE, 2012) ;
- **experimental projects** in residential areas, districts (Han, et al., 2007; Anh-Dzung et al., 2009; Petrucci et al., 2010), or even on watersheds (Moriyama et al., 2012) ; communication advertisement can be issued in parallel.

Some policies previously mentioned and their decision-making tools may have taken benefit from a preliminary evaluation of the expected benefits of rainwater tanks (UPRCT, 2005; Forasté et al., 2010). Such evaluations are numerous in the literature, as mentioned below.

3 CURRENT APPROACHES FOR THE EVALUATION OF THE BENEFITS OF RAINWATER HARVESTING FOR STORMWATER MANAGEMENT

3.1 Objectives and scale configurations

For SW management, a preliminary evaluation is likely to help maximize the design cases summarized in Table 1. For instance, for cases 2 and 3 (RWH and SWM put in parallel or in series), the idea is to look for methods not sizing rainwater tanks and source control measures one at a time and then sticking the two volumes together. Indeed, this traditional – and secure – method supposes that the rainwater tank is full prior any rainfall event and is likely to generate appreciable additional costs. The common thread of a preliminary evaluation is so to determine the influence of each parameter of the project – collection area, runoff coefficient, uses of rainwater, ... - on the benefits that can be provided for SW management. Studies carried out at the end of the 1990s were built on this rationale (Vaes *et al.*, 1999; Herrmann *et al.*, 1999; Coombes *et al.*, 2001, 2002). This rationale can also be found in more recent academic works aiming at defining easy-to-use sizing methods (Jensen *et al.*, 2010; Gerolin *et al.*, 2010; Okui *et al.*, 2012).

A preliminary evaluation can also be used to quantify the benefits on the local hydrological cycle of a general implementation of RWH practices in:

- urban projects such as housing estates or urban development zones (a few hectares) (Memon *et al.*, 2009; Huang *et al.*, 2009; Petrucci *et al.*, 2010; de Gouvello *et al.*, 2010) ; these simulations can be the continuation of previous simulations carried out at a smaller scale in view of their application in a broader context (Coombes *et al.*, 2002; Hardy *et al.*, 2004; Kellagher *et al.*, 2011) ;
- large geographical areas such as watersheds or even towns (a few square km) as part of the deployment of a local policy (Thomson *et al.*, 2005; Tahir *et al.*, 2009; Burns *et al.*, 2010; Petrucci *et al.*, 2010) ; such evaluations can act as important decision-making tools.

These preliminary evaluations often rely on « black box » models, only quantifying the reductions of stormwater flows or volumes at the outlet of the project, of the watershed, ... without necessarily looking for some comprehension of the phenomena inside the premises of the study.

The scale that is chosen for the evaluation of the benefits provided by a dissemination of rainwater collection systems determines the importance of such benefits. Some authors underline a weakening of the benefits as the implementation scales become larger (Coombes *et al.*, 2001; Guillon *et al.*, 2008; Huang *et al.*, 2009; Burns *et al.*, 2010); others show the interest of considering RWH for SW management only for collective buildings – where the uses which can be supplied by rainwater are more important – or for high-density areas (Herrmann *et al.*, 1999; Coombes *et al.*, 2001), unless RWH is only a component, among others, of the SW management system.

The concept of evaluation can also deal with socio-economic considerations that this paper is not intended to develop.

3.2 Model-based academic studies and evaluative criteria

The previously mentioned academic studies use a model-based approach, with a more or less detailed model and given hypothesis for the representation of rainfall events, rainwater tanks, uses of rainwater and so on. The authors can then select one or several evaluative criteria.

A first criterion is the comparison between peak discharges during a rainfall event at the outlet of a project including, or not including, rainwater collection systems (Coombes *et al.*, 2001, 2002; Hardy *et al.*, 2004; Thomson *et al.*, 2005; Memon *et al.*, 2009; Huang *et al.*, 2009; Burns *et al.*, 2010). This criterion relates to specific considerations for sewer networks capacities, based on a non-aggravation of peak flows after development. These considerations are representative of the choices made in the field of urban drainage in the past decades in France. The limited relevance of this criterion is quoted several times – benefits closely associated with the form of the rainfall event and hardly predictable a priori.

A second criterion consists in quantifying the influence of rainwater collection systems on the overflow frequencies and volumes from a plot or a SW drainage system (Vaes *et al.*, 1999; Herrmann *et al.*, 1999; Tahir *et al.*, 2009; Forasté *et al.*, 2010). This criterion can relate to rationales developed where the receiving water bodies are sensitive to chronic runoff pollution, such as the examples presented before in Australia and in the United-States.

A third criterion, also based on a volume perspective, is the quantification of the reduction obtained in

SW discharge volumes during a rainfall event (Coombes et al., 2002; Memon et al., 2009) or on an annual rainfall basis (Guillon et al., 2008; Jensen et al., 2010; de Gouvello et al., 2010). A last evaluative criterion, not very different from the previous one, is the estimation of the storage volume available in a rainwater tank before a rainfall event, on a seasonal or even on an annual basis (Coombes et al., 2001, 2002; Gerolin et al., 2010; Burns et al., 2010; de Gouvello et al., 2010; Okui et al., 2012). A level of confidence for this available storage volume can usefully be defined.

So, the current literature shows that the objective(s) to be addressed by a construction development or a local policy for SW management – water quality protection, flood prevention, ... - guide the selection of the evaluative criteria to be validated by decision-makers. A common and shared vision of the objectives to be addressed with the integration of RWH for SW management is a first step to ensure that the future policy will be well accepted and understood by local actors. For the example of the River Parramatta in Australia, prescriptions defined on the whole watershed have not been accepted as expected because of some Councils being reluctant to take RWH practices into account for flood prevention (Van der Sterren et al., 2009).

Experimental work to validate a theoretical model-based approach is quite rare on the field, except for lot scale where monitoring is easier (Van der Sterren et al., 2012). An example can be found in France, near Paris (Petrucci et al., 2010). In this study, rainwater tanks for outdoor uses (volumes smaller than 1 m³) have been installed in housings from a residential district (23 ha) of the little town of Champigny-sur-Marne. The impacts of rainwater tanks on the hydrological cycle of the district were first modelled using an hydraulic software and then monitored. Simulations carried out on the calibrated model using different scenarios have confirmed that the effectiveness of the tanks in reducing SW runoff is noteworthy during small rainfall events. As for the pilot project *The Shepherd Creek experience* in the State of Ohio, SW monitoring campaigns are conducted to evaluate the ecological and hydrological benefits of financial incentives for the installation of rainwater tanks and raingardens to turn to more decentralized SW management practices (Shuster et al., 2010). This experiment also focuses on the ability of the inhabitants to adopt these technical solutions.

CONCLUSIONS

Without trying to be exhaustive, the study presented in this paper aimed at identifying projects and local policies considering rainwater harvesting (RWH) for stormwater (SW) management in order to question on-going French practices, which tend to put RWH and SW apart. Projects identified in France, but mainly abroad, helped find some recurrent design principles, likely to be combined and made more complex at larger scales. A first simplified design typology has thus been introduced to create a common language. The examples of local policies put forward different levers that can be used by decision-makers to account for the potential benefits of RWH for SW management. Some of these policies are oriented towards the reduction of SW discharge volumes generated by imperviousness rather than the limitation of peak flows; this way of doing finds little consideration today in France. The different approaches identified showed that RWH could be considered for SW management to address multiple objectives, from the preservation of the quality of receiving waters during small rainfall events to flood prevention during stronger rainfall events. Further studies in France may consider the way of making the integration of RWH to SW management more formal to address the graduated level of services which are expected to be provided by drainage and stormwater management systems (MEDD et al., 2003; Geldof et al., 2008).

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