PREPARING APPROPRIATE WATER POLICIES FOR SD ANALYSIS: A BROAD-BRUSH REVIEW ON WATER CONSERVATION PRACTICES

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ABSTRACT

Water scarcity is one of the most serious modern-day problems with a continuously growing list of affected regions. In response, both international organizations and local governments have officially acknowledged this problem and have acted accordingly either by funding related research programs (the scientific community has been studying water scarcity for the last few decades) or by directly taking water demand management measures or by appropriate subsidies. As a result, there are nowadays examples of good practices/techniques that achieve considerable reduction of water demand. The scientific community, apart from suggesting new ideas, provides also feedbacks on these practices/techniques through scientific publications (e.g Zhang *et al*., 2009; March *et al*. 2004; Brewer *et al*. 2001; Surendran and Wheatley, 1998), which are usually thorough assessments of case studies based on some specific strategy, applied at a specific scale and serving a single sector. These reviews are valuable sources for further specialized studies and can serve as guidelines for the implementation of similar technical applications. However, the objective of these reviews is not to provide a broad-perspective picture of the available options suitable for each part of the urban water cycle. In this study, it is attempted to give a rough idea of this "broad picture" by providing an index of the representative best practices. To compile this index, first, the successful applications of water management practices/techniques found in literature were classified using three category types: the sector, the application scale and the employed water reduction strategy. Then, the basic characteristics of the representative best practices were assembled and presented in a compact and organized manner. These indicated best water management practices could be used to appropriately formulate representative water policies resulting from a system dynamics (SD) analysis that will take into account various socio-economic parameters. This will hopefully facilitate a quick uptake of the most promising options for each type of application.

Keywords: water scarcity, water conservation, water reuse, broad-brush review, system dynamics.

1. Introduction

This study attempts to provide a laconic and broad picture of the best available working examples of water saving practices concerning various parts of the urban water cycle. Three stages were employed in an effort to achieve the objective of this study comprehensively and concisely. In the first stage, the major categories that characterize the water saving techniques/practices were defined. Then, characteristic examples were collected for the prevailing category combinations. Finally, a summary table (an index) was assembled that codifies the information.

2. Materials and methods

The principal categories that characterize the water saving techniques/practices were assumed to be: the sector, the scale and the strategy. Table 1 provides the water demand per sector. The "Agriculture" includes the large scale irrigation in the production of agricultural goods. The "Environment" includes interventions to protect or remedy ecosystems (for example, aquifer recharge to avoid declination of groundwater level or seawater intrusion). The “Industry” includes the water consuming processes of industrial production. The “Water supply” includes the water consumed in residential and commercial areas.

Table 1: Water demand sectors.

Sector	Code
Agriculture	Ag
Environment	En
Industry	Id
Water supply	Ws

Table 2: Scales of the water saving practices/techniques.

Scale	Code
Household	1
Plant/Service building	2
Communal	3
Town	4
Region	5

Table 3: Water saving practices/techniques.

Strategy	Code
Alternative sources	Al
Efficiency	Ef
Internal recycle	Re
Symbiosis	Sb

Table 2 provides the application scales of the water saving practices/techniques. The “Household” refers to single family buildings or apartment buildings. The “Plant/Service building” refers to either factories or buildings where services are provided (e.g. hospitals, hotels, dormitories, etc.). The “Communal” refers to a small group that includes a number of entities of the two smaller scales (i.e. “Household” and “Plant/Service building”). The “Town” refers to a town and the “Region” refers to a larger area (e.g. prefecture).

Table 3 provides the standard general strategies that can be followed to reduce water demand. The “Alternative sources” includes the use of non-potable water for various water needs (e.g. rainwater, treated wastewater, seawater, etc.). The “Efficiency” includes the improvement of the efficiency in the water consumption processes. The “Internal recycle” includes the low scale (1 to 3 of Table 2) water reuse whereas the “Symbiosis” includes the high scale (4 and 5 of Table 2) water reuse.

Based on these categories a literature review was conducted. The results of this review are presented hereafter.

3. Results

The best examples found corresponding to the prevailing combinations of the three categories (Tables 1 to 3) are displayed in Table 4. The records of this table are sorted by sector, then by application scale and finally by water saving strategy. The location and a brief description of the technique/practice are provided.

Table 4: Classification of best technique/practice examples per sector/scale/strategy.

Sect.	Scale	Strat.	Location	Technique/practice	Ref#
Ag	5	Sb	Mexico City	Use untreated WW for irrigation	12
En	5	Sb	Barcelona, Spain	Use treated WW for eco-flows	4
Id	5	Sb	Sydney, Australia	Reuse WW	25
Id	4	Al	Salisbury, Austral.	Recharge aquifer with urban runoff	16
Id	2	Ef	Wyoming, USA	Install air-cooled condenser	3,22
Id	2	Re	Singapore	Recycle water from rinses	3,28
Ws	4	Al	Hong Kong	Seawater for toilet-flush	29,10
Ws	4	Re	Veurne, Belgium	Recharge aquifer with treated WW	11,26,1
Ws	3	Al	Lankwitz, Germ.	Rainwater for toilet-flush, 200 persons	15
Ws	3	Al+Re	Brisbane, Australia	Rainwater plus greywater, 22 lots	5,8,6,9
Ws	2	Al	Southampton, Uni.	Rainwater harvesting, Services Building	18
Ws	2	Ef	Chesswood, UK	PIR controlled urinals, middle school	23
Ws	2	Re	Mekong, Vietnam	Greywater recycling, campus dormitory	17
Ws	1	Ef	Miami, USA	Install efficient water appliances	13
Ws	1	Ef	Cyprus	Xeriscape shrubs, fabric/gravel covered	21, 27

* Note: See Table 1, Table 2 and Table 3 for description of codes in Sector, Scale and Strategy fields. Number of the reference is provided instead of the author names.

It should be noted that the example applications described in Table 4 are not panaceas for every seemingly similar situation since the operation of these techniques/practices depends on the temporal and spatial variation of the system stresses (e.g. precipitation, water demand, etc.). To ensure feasibility, optimum design and maximum benefits from the application of these schemes, appropriate tools that take into account the stochastic nature of the system stresses should be used during the preliminary design phase (Rozos and Makropoulos, 2015, 2013).

4. Conclusions

The recent developments in water saving practices and technologies have made available a variety of water saving options, each one following a different strategy and applied on a different sector and scale. This study conducted a broad, but systematic, literature review on these options. To achieve this, the study started with a scoping to gather the required information to put together the major categories that classify the water saving strategies. The basic features of the characteristic examples were presented in a compact and organized manner that hopefully will facilitate a quick uptake of the best available options by stakeholders. These indicated best water management practices could also appropriately formulate representative water policies resulting from a system dynamics (SD) analysis that will take into account various socio-economic parameters. These water management policies fed into an urban water cycle model will hopefully facilitate a quick uptake of the most promising options for each type of application.

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