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Reusing wastewater to cope with water scarcity: Economic, social and environmental considerations for decision-making

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ABSTRACT

Wastewater reuse has been recognized as an encouraging solution to cope with the problem of water scarcity around the globe. Adopting Integrated Water Resources Management principles will ensure that the implementation of wastewater reuse projects will take into account all the various types of affected stakeholders, accounting in addition for the external costs and benefits derived from the reuse decision. The objective of this paper is to analyze the economic, social and environmental aspects surrounding the concept of wastewater reuse in order to assist policy-makers and managers on the implementation of economic instruments for decision-making. This study proposes a methodological framework for conducting cost-benefit analysis, which is later exemplified by the Yarqon Recycling Project case study in Israel. In this case study application, 3 different scenarios (“pessimistic”, “base-case” and “optimistic”) with a range of parameters values, were used to estimate the most relevant internal and external costs and benefits. Additionally, the most influential parameters were identified using a sensitivity analysis that included both Monte Carlo simulations and the standardized regression coefficients method. For the “base-case” scenario, the net present value obtained was approximately $4.83 million. Although the feasibility of the project is demonstrated, the sensitivity analysis results were less favorable (likelihood of obtaining a positive result was only 64.28%), being the external recreational costs derived from irrigating with reclaimed wastewater the most influential parameter. The results of this analysis led to the conclusion that including the relevant externalities might have a strong impact on the economic feasibility of the wastewater reuse projects. The proposed methodological framework aims to guide decision-makers in evaluating their success with respect to Integrated Water Resources Management in economic terms.

1. Introduction

The management of water resources in many arid and semi-arid regions of the planet has been a big challenge for a long time due to water scarcity problems. Scarcity refers to the situation when the balance between the availability of usable water and the demand reaches a critical point (Collins et al., 2009). In many regions under water scarcity, intensive industrial and urban development, along with a large population growth especially in the cities, has caused severe pressure on local water resources. In addition, climate change is expected to further compromise the water quality and availability for supply as well as the functioning of aquatic ecosystems (Sowers et al., 2011; Meyer et al., 1999), increasing the need to find sustainable solutions to this compelling problem. In order to cope with water scarcity, one of the most promising supply-management practices to be explored is the reuse of wastewater (Pereira et al., 2002). Although irrigation is the traditional and more feasible reuse purpose for reclaimed wastewater, technological advances in the treatment field have enabled treatment facilities to obtain reclaimed water quality suitable for urban and even potable supply (Maliva and Missimer, 2012).

Several obstacles have hampered the implementation of this type of project. For instance, the tight compartmentalization of sanitation and supply sectors has limited the development of reuse schemes and consequently resulted in a mismanagement of water resources. Bridging supply and sanitation sectors into a more integrated approach is vital for achieving sustainable management of urban water systems (Lazarova et al., 2001; Bixio et al., 2006). Integrated Water Resources Management is a conceptual framework that tries to address this by encompassing and balancing all points of view of various water-related stakeholders, along with the complexity in the decisions they have to make. The resulting water management objectives and actions are therefore taken with criteria of sustainability in mind (GWP, 2000). Achieving good levels of

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integration among stakeholders will stimulate and boost communication between them and improve the decision-making process, which, in turn, will help avert future problems by understanding the regional water cycle (including interdependency of drinking water and wastewater as part of the same cycle), raising public awareness on current water management issues, and improving the understanding of different management options available at the regional level (Thomas and Durham, 2003).

Regarding the economic aspects of management, Integrated Water Resources Management considers water as an economic good. The decisions of the economic sector will not be water sensitive unless clear and consistent information regarding the trade-offs involved in a full value scale are made available. Once this is achieved, integration could enable each stakeholder representing a distinctive water sector to achieve its own goal/s more efficiently in economic terms, in a long-term perspective (Grigg, 1999). Cost-benefit analysis can be used as a decision-support tool to evaluate these trade-offs and the economic feasibility of the wastewater reuse projects. Cost-benefit analysis is based on the Kaldor–Hicks potential compensation criterion: A project should be supported if the benefits for the gainers are sufficiently greater than the costs of the losers, so they could in principle compensate the losers and still be better off (Kaldor, 1939; Hicks, 1943). Cost-benefit analysis provides a basis for rational thinking about losses and gains subjected to decisions. It further depicts the beneficiaries and losers (by "counting" utility or well-being) in both the spatial and temporal dimensions.

When applying cost-benefit analysis to evaluate wastewater reuse schemes, internal and external (economic, social and environmental) costs and benefits should be considered. However, many of these positive or negative externalities, defined as the experienced consequences by unrelated third parties of a given economic activity, are difficult to identify, let alone valuate because no explicit market for them exists (Hernández et al., 2006; Alfranca et al., 2011; Missimer et al., 2014). As of the time of writing, relatively few evaluation frameworks that address the challenge of identifying the most relevant externalities in wastewater reuse have appeared in literature (Marlow et al., 2011; Kandulu et al., 2014). The objective of this paper is to analyze the economic, social and environmental aspects around the concept of wastewater reuse to assist policy-makers and managers on the implementation of economic instruments for decision-making support in order to encourage Integrated Water Resources Management. From the results of this analysis, we develop a methodological framework to conduct cost-benefit analysis for wastewater reuse projects, which was later exemplified by a case study of a wastewater reuse plan in the Yarqon River (Israel).

1.1. Wastewater reuse configurations and benefits

Wastewater can be reused after treatment or untreated (or barely treated) for a variety of beneficial purposes (Bouwer, 2000). Here, we will consider wastewater reuse when the sewage from urban sanitation systems is used treated or untreated (raw sewage). Based on this definition, and the interaction of the water bodies in the water cycle, three main configurations of wastewater reuse systems are presented below.

1.1.1. Direct wastewater reuse

Direct wastewater reuse systems consist of directly using the reclaimed effluents for urban or agricultural purposes. Untreated or barely treated wastewater may be also allocated for irrigation of crops following some technical guidelines to reduce health and environmental risks (WHO, 2006). In spite of the possible potable uses (Leverenz et al., 2011), non-potable uses in this reuse system are more reasonable, such as for agricultural and urban park irrigation, fish farms, industrial uses (cooling, processing), fire fighting, dust control and toilet flushing among others (Abeysinghe et al., 1996; Üstün et al., 2007; Kim et al., 2009).

Direct wastewater reuse benefits are regularly mentioned in the reuse literature. The most relevant is making a new water supply source available. Besides, this new resource guarantees a high level of supply reliability because its production is not only relatively constant throughout the year, but also is constant between years (Friedler, 2001), which may bring increased benefits to users that suffer from constant water shortages (Mesa-Jurado et al., 2012). Increasing the resource availability entails decreasing the pressure on water stressed bodies (Miller, 2006). This new water resource also has the ability to boost the local economy, becoming satisfactory strategy to guarantee socio-economic and political stability in developing countries (Bdour et al., 2009). Direct wastewater reuse provides also an effective means of coping with nitrogen and other nutrients and pollutants present in effluents (Hernández-Sancho et al., 2010; Molinos-Senante et al., 2011). At the same time, direct wastewater reuse may reduce the dependence on other sources of fertilization (Toze, 2006; Fonder et al., 2010).

1.1.2. Natural water body augmentation

Reclaimed wastewater may be used to restore the previous characteristics of the natural water bodies' ecological status (Plumlee et al., 2012). Basically, this is the traditional wastewater disposal into a receiving media, but following predefined environmental enhancement objectives, and fulfilling certain water quality and quantity standards, to rehabilitate wetlands, wildlife refuges, riparian habitats, urban lakes, etc. Some of these pursued environmental enhancement objectives may range from conditioning the habitat to protect a unique endangered species (Garcia and Pargament, 2014), to restoring ecosystem functioning to a given degree, or even complementing these ecological objectives by enhancing the aesthetic or recreation values of the water body and to ensure the cultural sustainability of the reuse project (Nassauer, 2004). Most frequently this natural water body augmentation is incidental or unplanned. However, under water stress regimes, incidental natural water body augmentation is uncommon because there is less dilution capacity and secondary treatment of wastewater would not be enough to ensure the ecological quality restoration (Prat and Munné, 2000) thus requiring at least tertiary quality in such a case.

The benefits derived from natural water body augmentation are those obtained by improving the ecological status of the water bodies. There is an expanding body of literature on the issue of understanding the socio-ecological systems and how to account for the impact on the ecosystem services provided by ecosystems and their biodiversity that have no market. This impact can be monetized to assist decision-makers on the efficient distribution of the limited resources. There are several definitions of ecosystem services in the scientific literature. The most frequently quoted is the Millenium Ecosystem Assessment (MEA, 2005) definition, which defines ecosystem services as "the benefits humans derive from nature". In a similar manner, TEEB (2010) defines ecosystem services as "the direct and indirect contributions of ecosystems to human well-being". This latter definition supposes a difference between services and benefits, and that services can benefit society either in a direct or indirect manner (Fisher and Kerry Turner, 2008; Fisher et al., 2009), differing from Boyd and Banzhaf (2007) whose definition of ecosystem services does not include intermediate services, but only final. Both approaches can be considered as more appropriate for decision-making compared to MEA's since they are aimed at avoiding the double-counting problem (e.g. not valuing supporting and regulating services if these supporting services underpin the regulating ones) (Turner et al., 2003; Boyd and Banzhaf, 2007). Several authors have proposed