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Financial aspects of reclaimed wastewater irrigation in three sugarcane production areas in the Upper Cauca river Basin, Colombia

A. Galvis[a], M.F. Jaramillo[a], P. van der Steen[b,*], H.J. Gijzen[c]

[a] Cinara Institute, Faculty of Engineering, Universidad del Valle, Calle 13 # 100-00, Cali, Colombia
[b] Department of Environmental Engineering and Water Technology, IHE Delft Institute for Water Education, Delft, The Netherlands
[c] UNESCO Regional Office for Southern Africa, 8, Kenilworth Road, Newlands, Harare, Zimbabwe

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ABSTRACT

Treated wastewater may be reused for crop irrigation. This contributes to recovery of water and nutrients, and at the same time it helps to reduce pollution discharge to receiving water bodies. Despite these advantages of reuse of treated wastewater, there is little experience of this in Colombia and Latin America. In part, this condition is explained by the lack of studies that show the potential of reuse comparing the traditional wastewater treatment options without reuse versus the options with reuse. In this research, the financial viability of reuse of treated wastewater for the irrigation of sugarcane crops in the Upper Cauca river basin in Colombia was studied. The study included three cases, with different characteristics of wastewater (BOD_5 between 164 and 233 mg/L), flows (between 369 and 7600 L/s), rainfall levels (between 1009 and 1459 mm/year) and irrigation requirements (0.34 and 1.08 L/s-ha). For both scenarios, the same baseline was considered. Cost-Benefit Analysis CBA was used to compare the options (with and without reuse of treated wastewater). Cost of initial investment and O &M were considered. Benefits were considered like avoided cost by use of fertilizers, reduction of taxes for water use and discharges directly to water bodies and investment and O&M costs of infrastructure for irrigation with groundwater. The results of the CBA and sensitivity analysis show that there are two key factors that influence financial viability of treated wastewater for sugarcane crop irrigation: 1) the water balance and irrigation requirements, and 2) costs corresponding to the management of wastewater for agricultural irrigation, including additional treatment (if it is required) and the infrastructure to bring the treated wastewater to crops. The financial viability of reuse in the study area was limited because the values of tax for wastewater discharges and water tariffs in Colombia do not correspond to the values they should have.

1. Introduction

The reuse of treated wastewater for in agriculture for irrigation of crops puts demands on the municipal wastewater treatment technology to meet specific quality standards corresponding to the type of reuse (Brega Filho and Mancuso, 2003; Asano et al., 2007; U.S. EPA, 2012). Another main objective of wastewater treatment is to reduce the environmental impact on receiving water bodies via pollution reduction. The reduction of this environmental impacts may be achieved when treated wastewater is reused in activities such as crop irrigation, industrial processes, cleansing or washing activities (Becerra et al., 2015; Capra and Scicolone, 2007; Winpenny et al., 2013). Besides reusing water, this approach will also promote the reuse and recovery of other resources such as nutrients and energy (Gijzen, 2006, 2001). Additionally, wastewater reuse, being an additional source of water, represents environmental benefits such as maintenance of critical water flows in sensitive ecosystems and recreational activities. Treated wastewater reuse is the second step The Three-Step Strategic Approach (3-SSA). It presents an integrated approach toward pollution and water quality management, consisting of: 1) minimisation/prevention, 2) treatment for reuse, and 3) planned discharge with stimulation of self-purification capacity of receiving waters (Gijzen, 2006; Galvis et al., 2014). To ensure maximum impact and benefits, the three steps should be implemented together, preferably in a chronological order, and possible interventions under each step should be fully exhausted before moving on to the next step (Galvis et al., 2018).

Agriculture is the main user of freshwater, accounting for over 70% of the total global freshwater withdrawal from rivers, lakes and aquifers (UNESCO - IHP, 2014; Winpenny et al., 2013). For countries with low incomes (Gross National Income GNI < US$ 1005) or lower middle

* Corresponding author.
E-mail addresses: alberto.galvis@correounivalle.edu.co (A. Galvis), maria.f.jaramillo@correounivalle.edu.co (M.F. Jaramillo), p.vandersteen@un-ihe.org (P. van der Steen), h.gijzen@unesco.org (H.J. Gijzen).

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incomes ($US 1006 < GNI < $US 3955) this value corresponds to 82% (Amigos de la Tierra América Latina y el Caribe, 2016). On the other hand, wastewater is used in agriculture. However, in most cases effluent reuse in agriculture is done without any treatment, and this poses direct health risks. The Food and Agriculture Organization of the United Nations (FAO) reported that approximately 90% of total irrigation (with wastewater) is by untreated or partially treated wastewater (Winpenny et al., 2013). Millions of hectares are irrigated with raw wastewater in regions such as China, Mexico and India (Jiménez and Asano, 2008). In addition it is estimated that at least 20 million hectares are irrigated in 50 countries with polluted water (Jimenez and Asano, 2004). The main limitation of these reuse practices is that sewage is generally not (sufficiently) treated before reuse, which introduces public health risks and environmental impacts. The challenge is to develop adequate treatment systems that produce biologically safe effluents for public health, but which preserve valuable components such as nutrients, which may replace fertilizers.

The potential of reuse technologies has been considered primarily following the WHO and the United States Environmental Protection Agency U.S. EPA guidelines (WHO, 2006; U.S. EPA, 2012). WHO recommends natural (or extensive) systems, which are more viable in developing countries (tropical and subtropical), in terms of operation and maintenance. Although protozoa and helminths are key parameters to be considered in the reuse applications, because of their impact on health, they are not considered in the regulations of some developed countries. This is because in these countries the incidence of intestinal worm diseases is low (or zero). In contrast, the technologies used in developed regions to treat wastewater for reuse have high removal efficiencies for other pathogens (Jimenez et al., 2010; Moscoso et al., 2002).

In a study of the financial viability of reuse, the following types of benefits can be considered: 1) Savings on water use, the use of treated effluents will reduce the use of freshwater resources for irrigation; 2) Savings for the reduced use of fertilizers. Effluent reuse improves soil fertility contributing organic matter and macronutrients (N, P, K), thus reducing the use of chemical fertilizers (Corcoman et al., 2010; Hespanhol, 2003; Winpenny et al., 2013); 3) Reduction in sewer tariffs and tax for wastewater discharges directly to water bodies. The reduction of effluent discharges contributes directly to the improvement of the water quality of the receiving water bodies (Bixio and Wintgens, 2006); 4) Converting Chemical Oxygen Demand (COD) into energy. Wastewater treatment can be accomplished in aerobic or anaerobic systems, but anaerobic systems appear to be more favourable because of energy recovery and cost-effectiveness (Gijzen, 2001); 5) Savings on infrastructure and its operation and maintenance (O&M) for irrigation when groundwater is used. With the wastewater reuse in agriculture, groundwater is preserved since agricultural reuse will contribute a percentage of its recharge with superior quality characteristics (Moscoso et al., 2002). In addition to agricultural reuse, infrastructure costs and pumping groundwater may be avoided (Cruz, 2015). This strategy therefore contributes to reducing freshwater use, closing nutrient cycles, reducing pollution discharges into receiving water bodies, and reducing infrastructure and O&M costs. As such, effluent reuse reduces the eutrophication of water bodies and costs in freshwater and the use of agrochemicals in farming (Candela et al., 2007).

Despite the advantages mentioned above of reuse of treated wastewater, there is little experience of this in Colombia and Latin America. In Colombia, only raw wastewater is (illegally) used in agricultural irrigation. This situation has been generated mainly by: i) inadequate management of domestic wastewater, ii) undervaluation of wastewater as an alternative source of irrigation, iii) ignorance of the conceptual aspects for the implementation of reuse and iv) policies and regulations for the reuse management are not adequately articulated (Ministerio de Agricultura y Desarrollo Rural, 2011; Ministerio de Ambiente y Desarrollo Sustentable MADS, 2014). The assessment of the financial viability of reuse in agricultural irrigation can help stimulate reuse as a strategy for wastewater management. This assessment can be done using the cost benefit analysis CBA to compare the wastewater management considering reuse and without considering the reuse option. This study considers the local context regarding the type of reuse, the cost of raw water and local regulations. In this research, the financial viability of the reuse of treated wastewater in sugarcane crop irrigation in the Upper Cauca river basin in Colombia was studied. The research included three case studies, with different characteristics of wastewater, effluents flows from wastewater treatment, rainfall levels and irrigation requirements. For both scenarios (with and without reuse), the same baseline was considered and CBA was used to compare the two scenarios. A sensitivity analysis was performed for the irrigation requirements, water use fee rate and tax for wastewater discharges to water bodies (effluent charges). In this study an incremental analysis of CBA was employed (Boardman et al., 2001; Harrison, 2010). It does not consider the common costs and benefits, such as health benefits, of the two scenarios that were compared.

2. Material and methods

2.1. Study area

Upper Cauca river basin. The Cauca is the second most important river of Colombia and the main water source of the Colombian southwest. It has a longitude of 1204 km with a basin of 59,074 km^2. The study area is the Upper Cauca river basin (Fig. 1), in particular the corresponding to stretch La Balsa - Anacaro. La Balsa is 27.4 km (980.52 m above sea level (m.a.s.l) and Anacaro 416.1 km (895.56 m.a.s.l.). The 0.0 km corresponds to Salvajina dam. This stretch of the Cauca River has an average width of 105 m. The depth can vary between 3.5 and 8.0 m. The longitudinal profile of the river shows a concave shape with a hydraulic slope, which oscillates between 1.5×10^{-4} m/m and 7.0×10^{-4} m/m (Ramirez et al., 2010). The average annual rainfall varies between 938 mm (central sector) and 1882 mm (southern sector). There are two dry season periods: December - February and June - September. Rainy days per year vary between 100 days (central sector) and 133 days (northern sector) (Sandoval and Ramírez, 2007).

An important part of the sugarcane crops and the Colombian sugar industry are located in the flat area along the Upper Cauca river basin. In this flat area are the largest cities and therefore it is here where the largest amount of wastewater is generated. In the mountain area, there are coffee crops and associated industry. The Cauca River has been used for the last decades in fishing, recreation, power generation, riverbed matter extraction, domestic water supply, irrigation and industry. The Salvajina reservoir began operations in 1985 and it is part of a project aimed at improving flood control, water quality, self-purification capacity and power generation. The reservoir has a capacity of 270 MW. The reservoir operates with a minimum flow discharge of 60 m^3/s and an average daily flow rate of 140 m^3/s at the Juanchito station (Sandoval et al., 2007). The Cauca River receives solid waste and wastewater discharges from industrial and domestic sectors, which is contributing to the decline in water quality. In the study area, there are currently 3.9 million inhabitants and the Cauca River receives, in the La Balsa - Anacaro stretch, approximately 140 ton/d of Biochemical Oxygen Demand (BOD_5).

Selecting the case studies. This study area was selected considering: 1) the existence of large sugarcane crops with potential to be irrigated with treated wastewater; 2) scarce surface water for agricultural irrigation during sometimes of the year; 3) location of cities with wastewater treatment systems (existing and / or projected); 4) availability of information on the characteristics of the sugarcane crop, due to the existence in the region of a sugarcane research centre (Cenicaña); 5) hydro-meteorological information availability through Cenicaña and the regional environmental authorities; 6) availability of information on wastewater management through the service provider companies