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Review

# Constructing the ecological sanitation: a review on technology and methods

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ABSTRACT

Wastewater often contains valuable resources (e.g. organic matter and nutrients). Different from conventional sanitation approaches, the ecological sanitation (Eco-San) system is based on the closure of material flow cycles to recover resources with minimized demands on other resources. The review comprehensively summarized the main components of the Eco-San system (user interface, collection and conveyance, storage and primary treatment, and reuse/disposal), the frequently-used evaluation methods, and the framework of evaluation index system. Some typical practical cases were discussed to demonstrate the managerial implications and popularize the applications of the Eco-San system. The results show that the Eco-San systems are beneficial to resource efficiency, agricultural use of the organic matters and nutrients, and energy recovery although some shortages exist (e.g. high cost, cultural constraints, and complex operation and management). The evaluation methods can help to identify the restriction factors, contributing factors and measures to improve the efficiency of the future Eco-San system. The setting, selection and quantification are three critical steps when using the evaluation indices to complete the evaluation process. This study not only provides the methods for both developing novel Eco-San systems (combinations of the components) and improving the Eco-San systems (evaluation of the combinations) to solve the wastewater problem in rural areas. Considering the challenges or limitations in the Eco-San research, the recommendations for future research may mainly focus on the combination of different components, methods for sustainability assessment, quantification of the evaluation index, and implementation of more real Eco-San cases.



**Contents**



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## 1. Introduction

Nearly a half of the global population currently live without sound environment sanitation systems according to modern standard, most of them are in developing countries and many even haven't sanitary toilets. It is a grand challenge to provide environment sanitation systems and services for these people in accordance with affordability, durability, convenience, esthetic design, and effectiveness. Environmental degradation, resources shortfalls and population growth further fuel the vicious circle of poor sanitation. The conventional sanitation (Con-San), which is symbolized by water-flush toilets and mixed-wastewater collection (mainly via a gravitational sewer system with massive water as transportation medium), has so many disadvantages in the terminal treatments of wastewater and wastes, such as requiring complex equipment and expertise to operate and maintain, consuming enormous amounts of energy and resources while still leaving a lot of emissions to eco-environments (Sala-Garrido et al., 2012; Mo and Zhang, 2013; Thibodeau et al., 2014), that it is increasingly thought unsustainable in last decades.

In past decades, scientist and engineers have made great efforts, of which the ecological sanitation (Eco-San) is one representative. The term 'Eco-San' appeared in 1990's (Esrey et al., 1998) and quickly got a shot at stardom of the new millennium concepts. The United Nations issued a declaration of 'Eco-San-closing the loop in wastewater management and sanitation' in 2000 (Winblad, 2004). Then in 2001, IWA founded the Eco-San Group affiliating the Sustainable Sanitation Group in Berlin and held the 1st International Conference on Eco-Sanitation in Nanning, China (Jfnsson, 2001) but the events only continued for other two times (2003 in Lubeck, Germany and 2005 in Durban, the South Africa). In 2003, IWA let 'the Specialist Group on Eco-San' to take over 'the Sustainable Sanitation Group', but it was renamed to 'the Resources Oriented Sanitation Group' in 2007 (IWA, 2007).

The ecological sanitation (Eco-San) system is an alternative approach to realize sustainable sanitation. It is known as the resources-oriented sanitation and based on ecosystem approaches, the closure of material flow cycles, a novel trend of pollution treatment (from sewage disposal to resources reclamation), and a re-conceptualization of sanitation (from a 'drop-flush-forget' mode to environment protection at sources by means of 'drop and reuse' mode) (Haq and Cambridge, 2012; Langergraber and Muellegger, 2005). The Eco-San aims to meet socio-economic requirements, prevent pollution of surface and ground water, sanitize urine and feces, recover nutrient for food production, and save water, energy and resources in a given local context. It is considered more ready and suitable to be applied in rural areas, where the residence is more decentralized and nearer to farmlands than urban.

In last three decades, multiple types of Eco-San systems have been advanced with different user interface, collection and storage, treatment processes, and reuse or recycle of water and nutrients. For example, Guzha et al. (2005) evaluated the effect of using sanitized human excreta on maize production and water productivity, which recommended that ecological toilets should be added to the list of approved sanitation systems; Bdour et al. (2009) discussed several options to achieve sustainability in wastewater

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