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Feasibility, sustainability and circular economy concepts in water reuse

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Abstract

This review examines the feasibility and sustainability in wastewater reuse. Prior research has shown the need of changes in water utilization patterns, including the establishment of water reuse, to shift towards an efficient and sustainable water use. Nevertheless, the characteristics of local water markets have often determined the feasibility of water reuse systems, and economics have resulted in the major barriers to an actual development of water reuse. A Holistic Approach that takes into account all the reuse factors (political, decisional, social, economic, technological and environmental factors) is needed for a sustainable water reuse implementation. New policies based on circular-economy concept may lead to a "paradigm shift" that starting from the principle of segregation at source could establish a more sustainable model in wastewater management with an enhanced resource recovery.

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Water reclamation, Holistic approach, Centralized-systems, Decentralized-systems, Resource recovery, Paradigm shift.

Introduction

One of the most pervasive problems afflicting people throughout the world is inadequate access to clean water and sanitation. The growing global economy and population couple to make water a limited resource in terms of both quantity and quality [1]. Water also strongly affects energy and food production, industrial output, and the quality of our environment, affecting the economies of both developing and industrialized nations [1,2]. The World Economic Forum has listed the water crisis as the global risk of the most devastating impact [3]. In this context, water reclamation at wastewater treatment plants represents an important part of sustainable water resource management. Wastewater reuse can be applied for various beneficial purposes such as agricultural irrigation, industrial processes, groundwater recharge, and even for potable water supply after advanced treatment [1]. Furthermore, the always more urgent need for a more sustainable society is spurring new developments in sewage handling with the goals to recover all the resource available in wastewater (e.g., clean water, fertilizer, energy, bio-plastic, other materials), even in a viewpoint of on-site reuse in compliance with the new paradigm of "circular economy" [4–10].

This review is focused on the feasibility and sustainability of water reclamation and reuse. Particular emphasis is given to articles published in the last two years, which deal with the concepts of feasibility, sustainability and circular economy in water reuse.

Existing water reuse facilities and local driven implementation

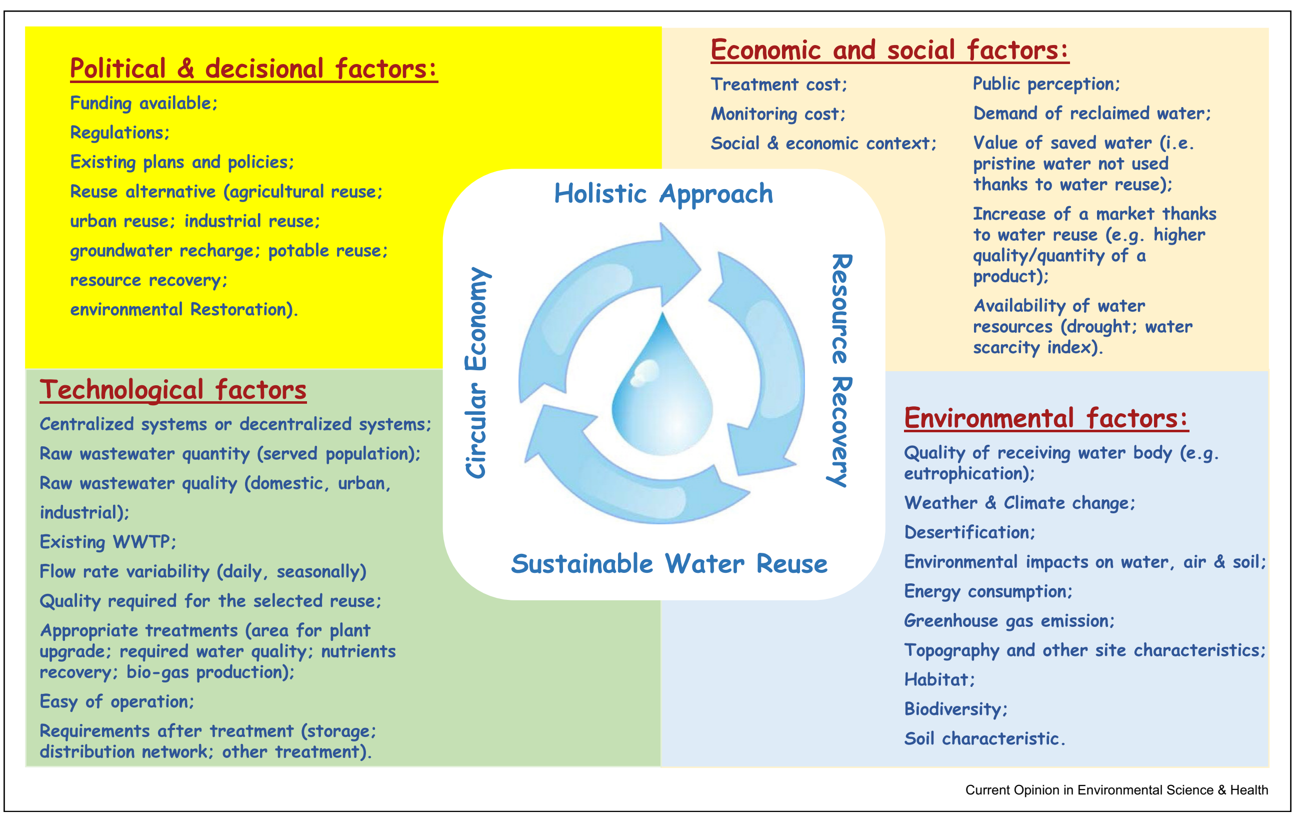
The existing worldwide water reuse systems can be mainly categorized as centralized and decentralized systems. Centralized or large-scale systems benefits from economies of scale in management and treatment costs but require significant investments in distribution systems to convey water for large distances [11]. These systems can serve several potable and non-potable applications including irrigation, industrial cooling, urban reuse, groundwater recharge and direct augmentation of drinking water supply [11,12]. Decentralized water systems, on the other hand, are implemented for smaller urban areas such as individual households, cluster of buildings or districts. They use different sources of water including rainwater and greywater and are usually realized for non-potable purpose (e.g., toilet flushing, car washing, garden irrigation) [11,12]. At this scale a very meticulous sources separation from sewage streams, including also yellow water (i.e., urine) and brown water (i.e., feces), has been proposed to maximize nutrients and energy recovery [13,14]. Decentralized water systems are often regarded as more sustainable than centralized systems because they increase the potential for water conservation and reuse, increase the resiliency of the water infrastructure network, and reduce the cost of infrastructure replacement [15].

Local constrains, including economic, political, environmental, social and technological factors often determine what water reuse scheme is best for the implementation in different regions of the World [12,16]. For example, in arid regions reclaimed water is generally applied in agriculture, whereas in urban areas with low availability of reliable water sources, potable and non-potable reuse applications have been developed. Particularly, in Japan dense urban areas and appropriate national policy requirements have favored the development of innovative dual recirculation systems and decentralized wastewater reuse schemes [17]. On the contrary, in California, high per capita water demand in densely populated cities has led to the implementation of several centralized indirect potable reuse (IPR) systems, where wastewater treated to follow regulatory limits similar to standards for drinking water production has been used to recharge groundwater or mixed with surface water, and then utilized for potable purposes [18,19]. In other cases, such as in Namibia and Texas, direct potable reuse (DPR) schemes, where purified recycled water is added directly to the drinking water distribution network, have been used or proposed to augment potable water supply due to a cost reduction for a non-needed development of an environmental buffer typical of IPR applications [12,20].

Economic feasibility and sustainability of water reuse systems

Many modern wastewater treatment plants (WWTPs) require high levels of energy (e.g., pumping, aeration) and resource consumption (e.g., chemicals) to transport and treat wastewater [21,22]. In the United States, some municipalities spend about 35% of their energy budget on water and wastewater treatment facilities [23], while in European Union countries, drinking water and wastewater treatments accounts for 7.6% of the overall energy consumption [24]. Thus, to facilitate sustainability, it is a common opinion that an economically feasible water management approach needs to be developed in conjunction with changes in water utilization patterns [12,25–27]. In order to assist decision-making on sustainable water reuse, a holistic approach-based model should be developed to take into account several factors, which could play a major role in the evaluation of reuse projects [28]. These factors can be ascribed as political-decisional factors, social-economic factors, environmental factors and technological factors as shown in Figure 1.

Figure 1



Holistic approach for sustainable water reuse.