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A comprehensive framework for the assessment of new end uses in recycled water schemes

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HIGHLIGHTS

- A framework for holistic assessment of new recycled water end uses was proposed.
- The potential and key issues for development of three new end uses were analysed.
- The alternative management strategies and evaluation criteria were discussed.
- The procedures and algorithms of multi-criteria analysis (MCA) were addressed.
- Quantitative models, surveys and case studies should be further performed.

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ABSTRACT

Nowadays, recycled water has provided sufficient flexibility to satisfy short-term freshwater needs and increase the reliability of long-term water supplies in many water scarce areas, which becomes an essential component of integrated water resources management. However, the current applications of recycled water are still quite limited that are mainly associated with non-potable purposes such as irrigation, industrial uses, toilet flushing and car washing. There is a large potential to exploit and develop new end uses of recycled water in both urban and rural areas. This can greatly contribute to freshwater savings, wastewater reduction and water sustainability. Consequently, the paper identified the potentials for the development of three recycled water new end uses, household laundry, livestock feeding and servicing, and swimming pool, in future water use market. To validate the strengths of these new applications, a conceptual decision analytic framework was proposed. This can be able to facilitate the optional management strategy selection process and thereafter provide guidance on the future end use studies within a larger context of the community, processes, and models in decision-making. Moreover, as complex evaluation criteria were selected and taken into account to narrow down the multiple management alternatives, the methodology can successfully add transparency, objectivity and comprehensiveness to the assessment. Meanwhile, the proposed approach could also allow flexibility to adapt to particular circumstances of each case under study.

1. Introduction

The growing environmental problems, including the diminishing natural water resources, greater water demand triggered by population growth and urbanisation, deteriorated water quality, and highly changing climate, have highlighted the importance of exploiting all other possible water sources before using-up limited surface water and groundwater supplies. Recycled water, which is the wastewater being treated to a specified quality in order to be reused again, has been increasingly considered as a supplementary water supply (Lazarova et al., 2003; DWR, 2009). The merits of recycled water use have been demonstrated all over the world. In addition to economic, social and environmental benefits, a distinct benefit of

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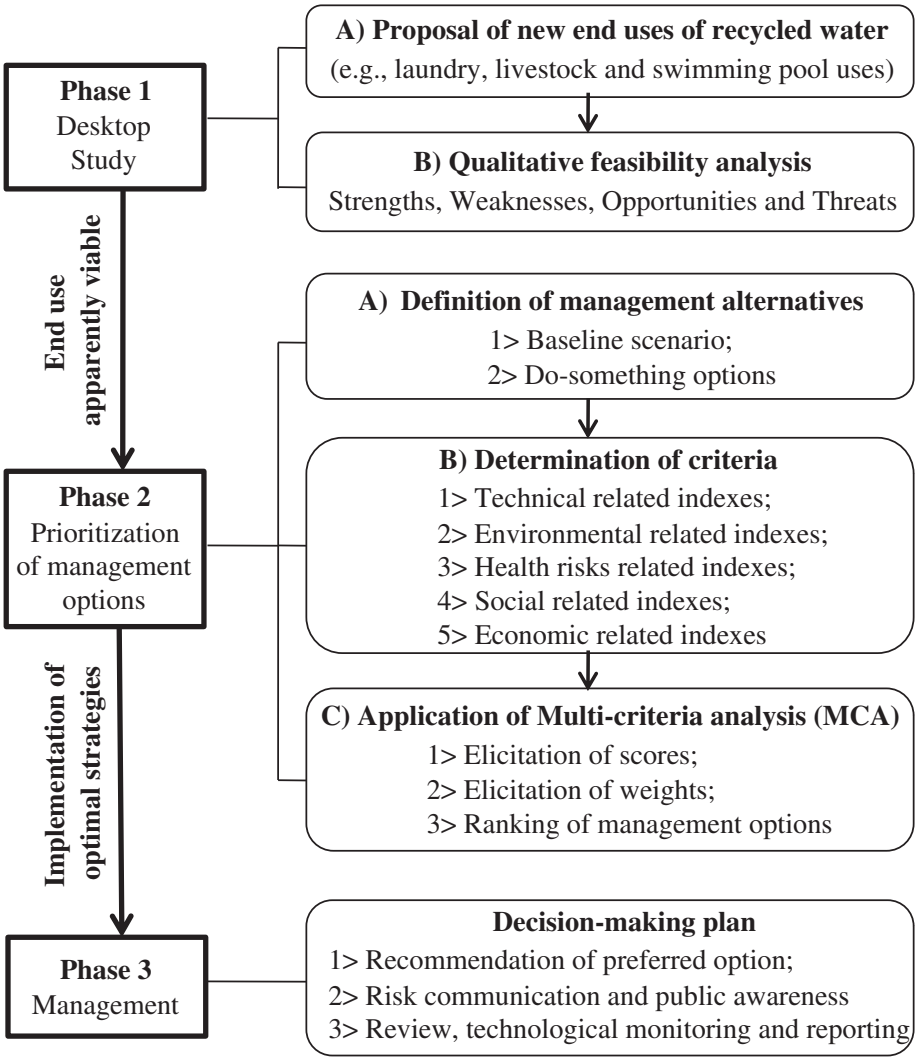

Fig. 1. Proposed framework for decision making in new end use management.
(Modified from Chen et al., 2012a.)

water reuse is the steadiness of water supply for both household and local industries, which is superior to rainfall-dependent water sources (Lazarova et al., 2012). Moreover, when bringing recycled water and other water resources together in management, the ecological footprint of water, sewage and drainage system could be potentially reduced by over 25% (Anderson, 2003). In a broader sense, water management can be further incorporated into climate change adaptation and environmental sustainable development (Angelakis and Durham, 2008; Asano and Bahri, 2011). However, despite apparent strengths of recycled water, the further adoption of water reuse might be affected by a variety of issues, including water rights, environmental concerns, public acceptance, and cost (NRC, 2012).

In developed countries, especially the cities and regions where freshwater resources are approaching the sustainable limit, recycled water would continue to be an important alternative water resource, especially for non-potable purposes (Chen et al., 2013a). More stringent water treatment standard (e.g., tertiary treatment and additional nutrient removal) is expected to be required in most recycled water schemes. As highly advanced technologies are available for producing clean water from wastewater without adverse health effects, the focus of motivating water reuse should shift away from technological issues to environmental, social and economic concerns (Van der Bruggen, 2010). While agricultural and industrial purposes are the dominant end uses of recycled water presently, urban and residential applications such as landscape irrigation, toilet flushing and car washing, are experiencing rapid development, the amount of which are likely to be as high as or much higher than that of agricultural irrigation schemes (Brissaud, 2010; Wild et al., 2010). High value end uses with potential close human contact (e.g., recycled water for household laundry and swimming pools) would be promising but still somewhat ambiguous due to strong public misgivings. Comparatively, in less developed countries, owing to technical and economic constraints, a large proportion of water reuse activities still involve secondary wastewater treatment. There would be a tendency in recycled water market towards higher level of treatment. With respect to end uses, apart from agricultural irrigation that will continue to be the major user of recycled water, other agricultural activities such as livestock consumption, using recycled water, can be beneficial to alleviate freshwater stress and maintain economic development. According to these recent trends in both developed and developing areas (Chen et al., 2013a), current end uses are mostly limited to a few non-potable purposes. To meet aggressive water recycling targets, beyond the implementation of more recycled water schemes, the development of new end uses might be prospective and should be realised accordingly.