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Stormwater reuse, a viable option: fact or fiction?

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Abstract

The increasing spread of urbanization is a common phenomenon witnessed in most parts of the world due to the perceived benefits of urban living. A compounding issue is the growing shortage of safe and reliable water sources. Perennial water shortages are becoming a common feature in many parts of the world. It is important to recognize stormwater reuse as a key resource for securing adequate future water supplies based on the concept of 'water fit for purpose'. These require careful prioritization of vulnerabilities, identification of the areas requiring adaptation and provide certainty of outcomes. Given the increasing inevitability of climate change it should be viewed as an opportunity to take advantage of new opportunities which stormwater reuse presents. This study identified key barriers to stormwater reuse and the difficulties in removing them.

Keywords: Reuse stormwater; water security; consumer psychology; urban water environments; storage space

1. Introduction

The increasing spread of urbanisation is a common phenomenon witnessed in most parts of the world due to the perceived benefits of urban living. This results in irrevocable changes to the landscape and creates economic, social and environmental impacts on a region. Currently about 53% (3.8 billion) of the estimated world population of 7.2 billion are living in urban areas (PRB, 2014) and this is projected to increase to 66% by 2050 (UN, 2014 a and b). A compounding issue in relation to the increasing urban and rural populations is the growing shortage of safe and reliable water sources (for example, see Mahanta et al. 2016). Seasonal and sometimes perennial water shortages are becoming a common feature in many parts of the world. On one hand, there is the escalating demand for residential, commercial and industrial uses (Hadadin et al., 2010, Wu and Tan, 2012). On the other hand, increasing living standards are also exerting pressure on water demand. This has led to unsustainable extraction of surface and groundwater resources and declining water quality in urban areas. The rate of depletion is further compounded by changes to rainfall patterns and increasing unreliability of the rainfall seasons (Bandara and Cai, 2014; Rosell, 2011; Strauch et al., 2015; Yaduvanshi and Ranade, 2015). A further undesirable consequence of urbanisation is the pollution of surface and groundwater resources from generation and discharge of a range of pollutants from anthropogenic activities. This limits the availability of safe water resources where treatment is economically feasible.

Under these circumstances, options such as desalination and inter-basin water transfers may appear attractive. However, these options can be cost prohibitive and may not be within the economic means of less affluent countries. One of the most common solutions to water shortages is restricting usage. This in turn impacts on human well-being and stifles economic growth. Unfortunately, the increase in demand and greater variability in weather patterns from climate change only serves to exacerbate the related issues of inability to meet water demand and declining quality, leading to water stress. In such a situation, stormwater presents a highly under-utilised resource (Managi et al., 2016). Depending on the level of rainfall in a particular region, stormwater can be either be the primary or the supplementary supply source.

2. **Challenges to reuse of stormwater**

Globally, stormwater reuse though popular (happening on a small-scale, barring Singapore) in some regions, is not widespread. This is primarily because stormwater reuse presents a number of distinct challenges. As rainfall is seasonal, it creates a level of unreliability. Appropriate storage capacity is a key requirement to ensure water availability during low or non-rainfall periods. Where subsurface characteristics are favourable, managed aquifer recharge is a viable option for storing stormwater underground. However, if geological conditions are unfavourable, costly storage reservoirs are needed. This uncertainty also needs to be considered in planning and designing stormwater storages. Furthermore, depending on its origin, stormwater can be highly polluted – in some cases more so than secondary treated sewage. Therefore, formulation of appropriate treatment strategies based on intended use is essential. These issues when considered together, give rise to the key challenge of ensuring reliability of supply at an economical cost, compared to other water supply options.

Stormwater reuse should be based on the concept of ‘water fit for purpose’. This entails use of water of different quality based on intended use. This allows use of water of varying quality and reduction in water treatment costs with the highest quality water used solely for direct consumption. These approaches need to be embedded into urban planning strategies. It also requires the adoption of a range of appropriate technologies which are already available. It does not require the development of new technologies, but rather the tailoring of existing technologies and application strategies to suit given situations.

There is universal consensus regarding the importance of water for enhancing human well-being. Access to safe water was a key focus of the Millennium Development Goals (MDGs) and has be re-inscribed into the Sustainable Development Goals (SDGs) adopted by the United Nations in 2015 (UN, 2014c).

It is also acknowledged that stormwater reuse helps reduce adverse impacts of urban stormwater runoff on the environment. Urbanisation results in quantitative and qualitative impacts. Quantitative impacts include increased runoff and higher peak flows, thereby increasing flood vulnerability. Qualitative impacts include transportation of physical, chemical and biological pollutants generated by natural and anthropogenic processes. Given stormwater reuse entails the storage of urban stormwater flows, its reuse will contribute to strengthening flood resilience and reducing pollutant loads to surface water bodies. Therefore, stormwater reuse will also contribute to improving urban water ecosystems.

Furthermore, urban water environments are important community assets. As urban population densities increase, water environments will play a more significant role as aesthetic and recreational resources (Asakawa et al., 2014). The need for 'islands of tranquillity' in congested built environments has been identified in the literature (Gobster and Westphal, 2004). In addition, degradation of urban water environments creates conditions for breeding disease vectors and vermin. There is confirmation of this occurrence in Brazil and some other countries in South America where there has been a rapidly escalating outbreak of the Zika virus.

A key reason for the current limited reuse of urban stormwater is because the true cost and benefits have proven to be difficult to assess. The application of quantitative economic tools alone is inadequate to take into consideration the qualitative benefits discussed above. Non-market valuation techniques are needed to evaluate community and environmental benefits and of stormwater reuse. In this case a holistic Multi Criteria Decision Making (MCDM) analysis employing market and non-market values is warranted.

However, decision makers need to consider barriers to adopting stormwater reuse. Although its use has been proven to work in a number of water stressed localities, it cannot be assumed that all cities and regions will adopt stormwater reuse. We, therefore, examine some barriers to stormwater reuse and how they vary between cities and regions.

Some foremost barriers relate to severity level of water stress, its duration, and costs associated with increasing the supply of water. If the costs of alternative technology (e.g., desalination) are less, then the use of stormwater reuse technology is less likely. Given desalination involves removal of salts and minerals, the resulting by-product is highly concentrated salt solution. If not disposed of appropriately, the salt residue results in environmental damage. Desalination is also energy intensive and non-renewable energy produces GHG emissions. Hence, non-marketed costs need to be taken into account if an unbiased assessment of benefits and costs between various water supply technologies is to be made. Furthermore, flexibility of existing systems and technology to process stormwater is a factor which could favour its use. Equally, method of water storage is an important consideration in justifying stormwater use.

Another not inconsiderable barrier is psychological. In many cases, it has become an impediment which dwarfs all others. This is especially so if the concept of recycling water has been newly introduced to residents. While education can certainly play a role, it is likely to be more effective in the long term. Clearly, in a country whose urban residents are already used to some form of recycling and/or fluoridation, then its use is less likely to be complicated. There can, however, be preferences based on other factors such as taste. Residents of countries, whose cities have traditionally relied on fresh water may have a higher resistance to recycled water, including stormwater. This is evident in countries (e.g., Australia) where there has been considerable resistance to the use not only of recycled water but also to fluoridation.

The public's psychological barriers in turn become political barriers and eventually become 'no go' areas for decision-makers. In such situations, lobby groups with commercial interests, often take the opportunity to lock-in this resistance. Removing such barriers can, therefore, be extremely difficult even where new technologies (e.g., stormwater reuse) is cost effective. In some countries, the presence of a top-down decision-making process can make it easier to adopt new technologies based on their merit. The presence of national security concerns (e.g., supply of water) can also contribute to more economically sound decisions. A country that faces water stress may for security reasons seek to diversify its water supply portfolio rather than rely on a single source, especially when depending on a neighbouring country (e.g., Singapore). Therefore, there are a wide range of direct and indirect barriers to stormwater reuse. The problems are likely to get worse with population growth, increasing demand from industry and uncertainty in rainfall.

3. Results

For this study we selected cities/regions where shortage of water is a growing problem and, therefore, its reuse is potentially possible. The cities of Beijing, China; Mexico City, Mexico; Delhi, India; Jakarta, Indonesia; South East Queensland (SEQ), Australia; London, UK; Sao Paulo, and Brazil are selected as our study areas. The following criteria are used for each country expert to assess the strength of barriers to stormwater reuse in their respective cities/regions. They are: policy openness to reuse stormwater; effectiveness of current stormwater reuse options; household affordability; consumer psychology; political patronage (e.g. subsidies for alternative technologies); institutional constraints (e.g. lock-in); lobbying from industries with vested interests; flexibility of existing technology to adopt stormwater reuse; importance of water security as a priority; storage space and fixed costs. Based on the responses we assess the strength of barriers to stormwater reuse. Table 1 summarizes the opinions of country/city water experts on the extent of barriers that exists to the adoption of stormwater technology.

Table 1: Assessment of strength of barriers to stormwater reuse

	Beijing, China	**Mexico City, Mexico**	**Delhi, India**	**Jakarta, Indonesia**	**SEQ, Australia**	**London, UK**	**Sao Paulo, Brazil**
Policy openness to reuse stormwater	very low	medium	medium to low	high	medium	medium	very high
Effectiveness of current stormwater reuse options	medium	high	very high	high	low	high	very high
Household affordability	high	high	very high	high	high	high	very high
Consumer psychology	low	high	medium	medium	low	high	high
Political patronage (e.g. subsidies for alternative technologies)	medium	medium	medium to high	medium	high	high	medium
Institutional constraints (e.g. Lock-in)	medium	medium	medium	high	low	high	medium
Lobbying from industries with vested interests	high	high	high	High	medium	very low	medium
Flexibility of existing technology to adopt stormwater reuse	low	high	low	low	low to very low	very low	medium
Importance of water security as a priority	low	very high	medium	high	low	low	low
Storage space	high	very high	very high	high	medium	low	low
Fixed costs	high	medium	medium to low	high	high	high	medium

Note: ‘Very low’ refers to a very low barrier; ‘low’ refers to a low barrier; ‘medium’ refers to a medium barrier; ‘high’ refers to a high barrier and ‘very high’ refers to a very high barrier.

Low household affordability is the largest barrier. The relatively low cost-effectiveness of constructing stormwater reuse systems is the primary reason, although it is mandated in some countries (e.g., Australia). Effectiveness of management options is the second largest barrier. Even though most cities listed have relevant regulations and legislation in place, there is a lack of effective implementation. For example, in Delhi, India, the city development plan only covers stormwater drainage without an integrated stormwater management strategy. This has resulted in little evidence of effective implementation of any of the guidelines/legislation relevant to stormwater reuse.

Storage space and fixed costs are the other set of barriers. Storage space is a result of the high urban population densities (e.g., Beijing, Mexico City, New Delhi and Jakarta). The related barrier of fixed cost is due to high cost of operation and maintenance. Although the initial expense of constructing a stormwater reuse system is not considered a major barrier, in most cities, the continuous investment in operation and maintenance is more financially challenging given that average income is low (e.g., Jakarta and Mexico City).

Policy openness to reuse stormwater, political, institutional and lobbying are relatively medium barriers to overcome. In terms of policy openness to reuse stormwater, most cities investigated have relevant regulations to achieve specific goals in reusing stormwater. However, some cities (e.g., Sao Paulo) have not included stormwater reuse in their legislation. In political terms, most cities included have promulgated regulations to provide financial support for stormwater reuse. However, this support can be illusionary and not very effective since the main focus is on urban flood control (e.g., in London and Sao Paulo). At the institutional level, lack of research relevant to stormwater is a significant issue. For example, (e.g., London), there is no single agency responsible for climate change issues. Additionally, although researchers (e.g., China) are undertaking studies on stormwater reuse, difficulty in obtaining baseline data due to lack of cooperation is a significant barrier. A common barrier in all cities relates to lobbying from other industries with vested interests and the difficulty in enhancing awareness and confidence of investors on the benefits of reusing stormwater.

Psychological barriers, the flexibility of existing technology, and national security are issues which are shown to be most easily overcome. Residents of cities (e.g., Beijing and Mexico) have a positive psychological response to reusing stormwater. Flexibility of existing technology is less of an issue for most cities given the requisite knowledge to support stormwater reuse is available and is, therefore, seen as a viable option. However, in Sao Paulo, the current knowledge is primarily related to the provision of stormwater storage ponds rather than stormwater treatment.

This study also indicates that importance of water security as a priority does not present a major difficult issue to overcome. For example, if Beijing were in danger of running out of water, a transfer from other regions in China is possible.

4. Conclusions

It is important to recognise stormwater reuse as a key resource for securing adequate future water supplies. These supplies are increasingly at risk not only from continued rapid population growth but also due to climate change. These require careful prioritisation of vulnerabilities, identification of the areas requiring adaptation and provide certainty of outcomes. Given the increasing inevitability of climate change it should be viewed as an opportunity to take advantage of new opportunities which stormwater reuse presents. In this study we identified key barriers to stormwater reuse and the difficulties in removing them. Furthermore, we also emphasise the need for a holistic MCDM analysis in order to account for true costs and benefits of using stormwater. We also emphasise differing importance of barriers in each city and the need for these differences to be well understood, if appropriate cost effective decisions on stormwater reuse are to be made.

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