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Wastewater reuse in the Eastern Caribbean: a case study

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Wastewater reuse is now widely recognised as an important source of water supply in water-scarce countries and a solution to environmental problems associated with untreated wastewater discharge. In the Eastern Caribbean, competition for potable water between tourism and local domestic needs has seen a growth of desalination treatment plants. The need for water by the tourism sector peaks during the dry season when availability is at its minimum. While desalination has been utilised to meet growing demands, hotels and resorts are now required, in many cases, to treat wastewater to a high standard to meet environmental standards so that the coastal areas, on which these hotels and resorts depend, are protected. This paper discusses the potential of wastewater reuse in the main tourism-dependent islands in the Eastern Caribbean. The nexus between desalination and wastewater reuse allows the hotels and resorts sector to reduce the overall costs of water supply, overcome shortages in the dry season and meet stringent wastewater disposal requirements, as it was found that wastewater reuse can meet up to 38% of total needs. In many of the islands, there are suitable conditions for promoting wastewater reuse.

1. Introduction

The increasing scarcity of fresh water in many parts of the world has seen the use of water and the disposal of wastewater having significant environmental and economic importance. By 2025, it is estimated that 1·8 billion people will be living in countries or regions with absolute water scarcity while two-thirds of the world population could be under conditions of water stress (UN Water, 2007). These conditions have led to conflicting demands on existing water systems and forced water providers to look at alternative sources of fresh water such as rainwater harvesting and wastewater reuse. The recent growth of wastewater reuse is driven by environmental policies for promoting sustainability in water resource management and economic concerns, but is constrained by issues dealing with safety, legislation, public perception, trust and acceptance, and collaboration and communication.

From a public policy perspective, reuse of wastewater addresses both water supply and pollution issues (Wu *et al.*, 2013). It can be an important element of water resources development and management, helping to close the loop between water supply and wastewater disposal (Leverenz and Asano, 2011). The early intensive use of wastewater can be found in Israel, where reclaimed municipal wastewater was used for agriculture and groundwater recharge. The practice emerged as a solution to severe water shortage, high water consumption and wastewater production, and the threat of wastewater pollution (Jiménez and Asano, 2008). By 2003, between 65% and 70% of wastewater of urban and industrial origin was reused in agriculture (Icekson-Tal *et al.*, 2003) and in the case of the Dan region reclamation project, an estimated 130 Mm^3/year is reclaimed. In Windhoek, Namibia, since 1968, direct potable reuse of treated wastewater has been in place and currently highly treated recycled water is put into a drinking water system that serves 250 000 people (National Water Research Institute, 2010).

In some parts of Europe, reclaimed wastewater is used in well-established agricultural and landscaping irrigation programmes (Lazarova and Bahri, 2005) and to meet the demands of golf courses that are fundamental to tourism (Marecos Do Monte, 2008). It is noted that in some parts of the world, golf course irrigation is the most rapidly growing application of wastewater reuse (Valentina *et al.*, 2012).

Many countries are allocating resources to improve wastewater reuse studies and applications, and are establishing guidelines for that purpose. The appropriateness of wastewater reuse depends on careful economic considerations, the potential users of the water and the relative stringency of the water discharge requirements (Asano and Bahri, 2011). A strategic approach to wastewater reuse must, however, be based on a systematic analysis of the situation and on the principle that water must not be used at a higher quality than is strictly needed (Pagella *et al.*, 2000).

As in many other regions, the small island developing states (SIDS) of the Caribbean have become concerned about water security, as some islands are on the threshold of water scarcity (WWC, 2000). Water scarcity in these small islands is exacerbated

by the constrained limited freshwater resources base, which poses particular challenges for freshwater resources management (Greene, 2009). Moreover, there is a growing pressure on freshwater resources owing to the high dependency on the tourism sector (equivalent to 40% of gross domestic product (GDP)) which is associated with high water use during the dry season when water availability is at its minimum.

Per capita water use in tourism has been estimated at between 1·5 to 2·5 times the domestic use per capita (Tapper *et al.*, 2011). In the Caribbean the average water usage per guest night in hotels is around 825 litres (EarthCheck Research Institute, 2013). For example, at the Sandals, in Antigua, the estimate was 720 litres in 2013 (Sandals, 2013). Additionally, luxury hotels can generate around 180 litres of wastewater per guest night (European Environment Agency, 2003). The high consumption of water in the tourism industry can be linked to extensive landscaping, water parks, swimming pools and golf courses.

To meet the high demand for water in the tourism sector, some tourism entrepreneurs in the Eastern Caribbean islands have turned to the use of desalination and treated wastewater reuse. As early as 1999, Singh and Clouden (1999) reported that a number of hotels in the Eastern Caribbean were practising wastewater reuse with some success.

The availability of current information on wastewater generation, treatment and use is crucially important for policy makers, researchers and practitioners to develop national and local action plans. For example, in the Eastern Caribbean, only Antigua and Barbuda has partial data (Sato *et al.*, 2013). This paper considers the status of wastewater reuse in the Eastern Caribbean (Figure 1) and the potential for wastewater reuse, particularly in the tourism sector. It also considers challenges in adopting wastewater reuse practices that are peculiar to the region.

Figure 1. Eastern Caribbean islands

2. Methodology

Water supply, its usage and wastewater generation were quantified for the usage of water and the generation of wastewater in the islands by reviewing government documents by way of desktop studies and was supplemented by interviews with water utilities professionals. Estimates of rainwater use were based on the number of households practising rainwater harvesting (RWH) and the average size of RWH storage facilities on the islands. Estimates of water consumption by tourism in the islands were computed based on the highest number of stay-over and cruise ship visitors in the past 10 years using statistics from national statistics offices, the Caribbean Tourism Organisation and the Eastern Caribbean Central Bank. A review of the wastewater reuse practices in the Eastern Caribbean was carried out by analysing available documents and personal discussions with key operations in the water sector in the islands during the annual conference of the Caribbean Water and Wastewater Association in 2013.

Following the work of Hochstrat *et al.* (2005), the wastewater reuse potential was estimated for two five-star hotels and resorts, one each in Antigua and St Kitts. Toilet needs were estimated at 13·26% of total water use based on the work of Cremona and Saliba (2013). Irrigation needs were computed based on irrigated area, average monthly rainfall and evapotranspiration for the location.

2.1 Water status in the Eastern Caribbean

The rainfall and freshwater availability in the islands of the Eastern Caribbean vary from plentiful in Dominica, where there is high rainfall averaging over 2000 mm annually, to scarce in Antigua and Barbuda, and some of the other small islands where average annual rainfall is less than 1000 mm, as shown in Table 1. For St Vincent and the Grenadines and Grenada, rainfall is much higher on the main islands of St Vincent and Grenada than their smaller dependencies of the Grenadines and Carriacou and Petite Martinique. According to ECLAC (2010), in the Eastern Caribbean, there is a projected 10–30% change in rainfall for the future due to climate change.

Typically most of the islands depend on more than one source of

Country	Annual rainfall range and mean: m	Sources of water supply			
		Surface	Ground	Rainwater harvesting	Desalination
Anguilla	0·46 to 2·05 (0·89)	L	x	X	X
Antigua and	0·89 to 1·40 (1·04)	x	x	x	x
Barbuda	0·51 to 0·99 (0·90)	L	–	X	x
Barbados	1·14 to 2·15 (1·42)	L	x	x	x
Dominica	1·80 to 7·62 (3·15)	X	x	x	–
Grenada	1·00 to 4·00 (2·23)	X	x	x	x
Carriacou	0·89 to 1·37 (1·08)	L	L	X	x
St Lucia	1·32 to 2·54 (1·55)	X	x	x	–
St Vincent	1·50 to 3·80 (2·31)	X	x	x	–
Grenadines	0·8 to 1·4 (1·25)	L	L	X	X
St Kitts	1·02 to 3·8 (1·42)	x	L	x	x
Nevis	0·90 to 2·20 (1·27)	x	L	X	–

Table 1. Rainfall and available water resources in the Eastern Caribbean (X = major, x = minor, L = limited)

water supply and the importance of each source varies from island to island, as shown in Table 1. Dominica is almost entirely dependent on surface water, with sufficient for hydropower, irrigation and export. In some of the smaller islands, such as Anguilla and the Grenadines, where there are no permanent rivers and groundwater is limited, the main freshwater source is RWH. Furthermore, as there are two distinct rainfall seasons, the combination of sources varies from season to season. For example, in Antigua and Barbuda, surface water, groundwater and desalination are used in the proportions of 5%, 20% and 75% respectively in the dry season and 25%, 15% and 60% respectively in the rainy season (US Army Corps of Engineers, 2004).

3. Estimating water consumption by tourism in Eastern Caribbean

Statistical information on water consumption in the tourism sector is generally limited (European Commission, 2009). Tapper *et al.* (2011) estimated that, in Barbados and Jamaica, the tourism sector consumes 16·6% and 14·24% of total water respectively. In the case of Barbados, water demand projection for the tourism sector for 2016 is estimated to be about 14·8% of total demand (Government of Barbados, 2008). Using average per capita water use by stay-visitors of 350 litres/person per d and 110 litres/person per d for locals, the water used by the tourism sector as part of the total consumption was estimated for each island and is shown in Table 2. These estimates range between 7·6% and 20·2%. The estimate for Barbados is slightly smaller than that reported in the literature.

These estimates, if projected for the future, may increase significantly due to climate change. Climate change and sea level rise are expected to have a considerable impact on water availability, and in particular on the tourism–water resources relationship (Cashman *et al.*, 2010). One projection is that, by 2016, the total demand for water by hotels, ships and golf courses will be approximately one-third of projected domestic demand (Emmanuel and Spence, 2009). Currently, as in most of the islands the local domestic demands are not yet satisfied, the competition between domestic and tourism demands is likely to intensify.

Country	Consumption as percentage of local domestic consumption: %		
	Stay-over visitors	Cruise-ship visitors	Total visitors
Anguilla	9·5	0·7	10·2
Antigua	19·4	0·8	20·2
Barbados	12·9	0·2	13·1
Dominica	7·0	0·6	7·6
Grenada	8·8	0·3	9·1
St Lucia	10·0	0·4	10·4
St Vincent and the Grenadines	8·3	0·1	8·4
St Kitts and Nevis	12·8	0·9	13·7
Tobago	9·0	0·1	9·1

Table 2. Estimates of water consumption by tourism as a percentage of local consumption (total visitors used as a proxy for tourism sector)

4. Wastewater reuse practices in the Eastern Caribbean

With few exceptions, such as Singapore, wastewater reuse for potable water is rare on islands (Falkland, 2002). However, wastewater reuse is possible for non-potable purposes in many small islands. During water shortages, Caribbean people have recycled water. Prior to the development of public water supply systems, the reuse of wastewater for domestic and agricultural purposes was practised at the household level.

Although the traditional household practices of wastewater reuse have declined recently, in the tourism sector it is experiencing growth due to the pressure on conventional water resources. This growth is facilitated by treatment technologies that produce high-quality water to satisfy most non-potable demands. The importance of wastewater reuse in the islands is influenced by the availability, type and cost of existing water supplies, and the existing wastewater systems (Table 3). For example, wastewater reuse is important in Barbados and Antigua and Barbuda; the desalination on which they are dependent is much more expensive than water supply from surface and groundwater.

Barbados is serviced by two municipal sewage treatment systems, where several package treatment plants collect about 25 000 m^3 of wastewater per day. The municipal plants discharge directly to the marine environment. Typically, treatment plants for the hotels have capacities ranging from 13 m^3/d to 170 m^3/d (UNEP, 1999); for example, the 88-room Coral Reef Club, Barbados, treats 114 m^3/d of the resort's wastewater from guest rooms and kitchens. Overall, less than 10% of the island's generated wastewater is being collected in a way that allows it to be treated for reuse (The Barbados Advocate, 2010). There are three main drivers for the reuse of wastewater in Barbados: satisfying the high tourism demand, groundwater protection and the reduction of the pollution of coastal waters.

In Antigua and Barbuda, where 70% of the water supply comes from desalination, and which has a high retail price for water of US$4·07/$m^3$ (Bento, 2013), the motivation for wastewater reuse is driven by high prices of water and restriction of wastewater disposal. Treatment plants in Antigua and Barbuda produce about 4440 m^3/d with varying quality of treated water. Many of the plants are small and only about 20% of the treatment plants handle more than 25 m^3/d. Most hotels with 50 or more rooms have on-site wastewater treatment plants and reuse wastewater for irrigation (Bento, 2013). One large hotel which uses 545–590 m^3 of water daily recycles 365–410 m^3 of it daily for irrigation use (Sandals, 2013).

In St Kitts and Nevis, the treatment of commercial and domestic wastewater is limited, partly due to the small population and the limited industrial and commercial activities (Chapman *et al.*, 2012). Wastewater reuse for the irrigation of golf courses has recently been introduced by the St Kitts Marriott Hotel. The hotel treats 272 800 m^3 of wastewater annually and utilises 87% of it for golf course irrigation (Chapman *et al.*, 2012).

There is no centralised wastewater treatment in Dominica and, as a result, the only wastewater reuse practice is that of grey water disposal to garden plots, but mainly during the dry season. In Grenada, wastewater reuse practices are also limited to households; however, potential has been recognised in an integrated

Country	Surface water supply: m^3/d	Groundwater supply: m^3/d	Domestic rainwater harvesting: m^3/d	Desalination supply: m^3/d	Wastewater treatment: m^3/d	Municipal wastewater coverage: %	Municipal water reuse: %	Hotel and resorts water reuse: %
Anguilla	0	0		4730	0	1·2	0	NA
Antigua	2211	1880	2320	9040	4810	4·2	4	
Barbuda	0	371	670	227	0	7·4		<10
Barbados	0	140 929	< 100	18 184	25 003	42·7	0	≈ 4
Dominica	45 461	336	327	0	NA	14·6	0	0
Grenada	43 200	1890		570	nil	8·0	0	<1
Carriacou	0	125	1410	590	0	0	0	0
St Lucia	41 000	0	760	0	0	13·2	0	NA
St Vincent	23 150	0		1090	213	11·6	1	>1
The Grenadines	0	NA	928	2445	0	0	0	≈50
St Kitts and	9863	2592	260	4731		5·6	0	16
Nevis	1690	6769	900	0	NA	6·4	0	2·3

Table 3. Domestic water consumption and wastewater disposal levels in the Eastern Caribbean (source of data column on 'Municipal wastewater coverage': Caribbean Development Bank (2012))

water resources management roadmap for the island (Government of Grenada, 2007). Wastewater reuse in St Vincent is limited to household reuse for backyard gardening. On the other hand, in the Grenadines, Young-George *et al.* (2007) reported that 39% of the resorts used treated wastewater. In Anguilla, although there is no municipal wastewater reuse, all hotels practise some form of wastewater reuse.

Unlike the small Eastern Caribbean islands, in Trinidad the Beetham wastewater treatment plant (BWWTP), one of the largest in the Caribbean, produces 75 700 m^3/d of high-quality effluent and, according to the Water and Sewerage Authority (WASA), the effluent exceeds standards for many countries that use wastewater for industry and irrigation purposes. During the 2010 drought, Petrotrin (a national refinery) supplemented its raw water supply with 3800 m^3/d from treated wastewater from the BWWTP. Furthermore, a project is currently being undertaken to transport this treated wastewater to the major industrial parks (NGC, 2013).

Overall, in the Eastern Caribbean, the level of wastewater reuse is influenced by freshwater availability (Table 3), which is reflected in prices (Table 4), the sources of domestic water supply to hotels and resorts (Table 3) and the size of the hotel industry. Thus, where there is a high dependence on desalination and/or RWH there is a tendency for greater use of wastewater. The price of potable water (Table 4), which is influenced by availability, has been indicated by hotel operators to be a determining factor in the decision making on wastewater reuse.

5. Wastewater reuse challenges in the Eastern Caribbean

Notwithstanding the growth of wastewater reuse worldwide, programmes and projects on wastewater reuse encounter a number of technical, economic, social, regulatory and institutional challenges. Specifically, some of the water quality concerns and questions regarding the evaluation of long-term environmental, agronomic and health impacts remain unanswered. In the Eastern Caribbean, the basic principles on which wastewater reuse is founded, namely (*a*) providing reliable and adequate treatment of the wastewater to meet strict effluent quality requirements; (*b*) protecting public health; and (*c*) gaining public acceptance (Asano and Bahri, 2011), are influenced by cultural and social constraints, state of the economy, technology and the availability of alternative sources of water. Thus, the key challenges to wastewater reuse in the Eastern Caribbean include resource sustainability, public policy and regulations, as well as economic technological considerations.

5.1 Resource sustainability

5.1.1 Availability of the wastewater

Before wastewater can be reused, it must be collected and treated. However, in developing and low-income countries such as the Eastern Caribbean, only 8% of the wastewater generated is treated (Toshio *et al.*, 2013). About 52% of households are not connected to wastewater treatment plants, and less than 2% of urban sewerage is treated before disposal (Emanuel, 2010). Moreover, in the Eastern Caribbean, where wastewater is collected, 85% of it is disposed untreated through an ocean outfall (Emanuel, 2010). The poor state of wastewater treatment in the

	Prices of water			
Country	Municipal: US$/$m^3$	Hotel: US$/$m^3$	Domestic/USA national average[a] (source US EPA, 2009)	Hotel/domestic
Anguilla	4·12	5·41	7·80	1·31
Antigua	2·96	4·08	5·60	1·38
Barbuda	2·96	4·08	5·60	1·38
Barbados	1·75	3·93	3·31	2·25
Dominica	1·48	1·48	2·80	1·00
Grenada	0·45	1·73	0·85	3·84
Carriacou and Petite Martinique	2·39	14·60	4·52	6·10
St Lucia	0·91	1·79	1·72	2·00
St Vincent and the Grenadines	0·90	1·79	1·70	2·00
St Kitts and	0·81	1·21	1·53	1·49
Nevis	2·70	2·70	5·11	1·00
Tobago	0·34	0·34	0·64	1·00

[a] USA national average ($2·00/1000 gallons).

Table 4. Price of water in the islands

wider Caribbean and the need for urgent action has resulted in the establishment of the Caribbean Regional Fund for Wastewater Management (Emanuel, 2010) under the Global Environment Facility (GEF). Better collection opportunities are available to the hotel sector, as hotels in the Eastern Caribbean tend to be located in clusters, making it easier for central collection.

5.1.2 Reuse during the rainy season

During wet periods, particularly during the rainy season, reuse of wastewater may not be needed for irrigation purposes (hotels, golf courses, public parks, businesses and homeowners) and the challenge becomes how to dispose of this water during such periods.

5.1.3 Contaminants of emerging concern

Chemicals that previously had not been detected are now being discovered in water or are being detected at levels that may be significantly different than expected. These chemicals, referred to as contaminants of emerging concern (CECs), can be broadly defined as chemicals that have been recently detected in the environment and may pose public health or ecological risks. CECs identified in wastewater discharges include household and industrial chemicals such as flame retardants, plasticisers, detergent compounds, pharmaceutical and personal care products (PPCPs), fragrances and antimicrobial cleaning agents (Esposito *et al.*, 2007).

5.2 Public policy and regulatory challenges

The Caribbean water sector faces a number of governance issues including political interference, ineffective regulatory frameworks, general absence of self-financing, weak formal institutions, lack of effective prioritisation in budgetary allocations and insufficient operational capacity. Such governance issues can challenge the wider application of wastewater reuse.

There are two critical questions.

(*a*) Who regulates wastewater reuse?
(*b*) For households that use untreated grey water for kitchen garden plots, should there be regulations to protect human health?

The answers to these questions may be found from the experiences of other countries such as Israel and Australia, where local and national guidelines have been developed for wastewater reuse, particularly for industrial and agricultural uses. This approach has been taken by Barbados, when in 2013 it began developing standards based on the United States Environmental Protection Agency (US EPA, 2012) guidelines, but to meet the island's specific needs (Jordon and Mwansa, 2013).

The basic requirements of its legislative policy are intended to provide an enabling environment and controls so that

(*a*) the safe reuse of domestic wastewater is in the public interest and all such wastewater should be put to beneficial reuse to the extent that the benefits compare favourably against costs
(*b*) implementation of domestic wastewater reuse projects requires the consideration of all relevant factors and risks including public health, environmental, economic, scientific, energy and public perception
(*c*) in no event may water reuse be implemented if it poses a threat to public health (Jordon and Mwansa, 2013).

In 2008, Antigua and Barbuda proposed water quality guidelines, with a primary purpose of ensuring that water quality on the island is maintained in a satisfactory manner; these recommend a licensing regime that requires hotels and wastewater industrial agencies to apply and receive permits to discharge effluents in coastal areas in Antigua and Barbuda (ESAL, 2008). It is suggested that the urban wastewater treatment directive (91/271/EEC) (EC, 1991), which requires secondary treatment for domestic and industrial wastewater, could be a starting point for wastewater treatment in the island (ESAL, 2008). This is a piecemeal approach as it only address wastewater disposal from one economic sector.

5.3 Financing wastewater treatment

A financial assessment for wastewater treatment and disposal (WWTD) in the Caribbean (UNEP/CAR-RCU, 2009) has shown that the costs of developing adequate systems are extremely high. Based on 2012 national estimates, the cost of full wastewater treatment (shown in Table 5) for the islands is between 25% and 119% of the annual GDP. These estimates exclude the cost of an independent pipe network to bring the water to the point of use. Such high financial requirements mean that the national governments are constrained in raising the necessary capital, which makes it virtually impossible for many of the islands to attain full wastewater treatment in the near future. Furthermore, private sector involvement in wastewater management is constrained by its financial unattractiveness owing to high capital intensity, political pressures to keep tariffs low and deficient regulations ((UNEP/CAR-RCU, 2009).

5.4 Technology selection

One of the main challenges for the reuse of wastewater is selecting an appropriate treatment system such that the effluent is of acceptable microbiological and chemical quality (Casani *et al.*, 2005). Ultimately, the choice of a treatment system would depend on cost effectiveness, safety, influent water quality, existing standards and capacity. In the region, a number of technologies are being used. For example in Antigua and Barbuda, there are five different types of wastewater treatment plants with sequencing batch reactors (SBRs), modified SBR being the preferred type. In small economies, the proliferation of different systems limits the advantages for efficiency of scale and makes the operation and maintenance highly dependent on external expertise.

Countries	GDP: US$ million (2012 estimate)	Costs of WWTD: US$ (UNEP/CAR-RCU, 2009)	Required investment as percentage of GDP: %
Antigua and Barbuda	1176·35	675 934 507	57·46
Barbados	4323·80	2 304 285 329	53·29
Dominica	479·64	118 081 895	24·62
Grenada	789·54	885 614 216	112·17
St Kitts and Nevis	748·49	421 721 055	56·35
St Lucia	1188·44	1 349 399 509	113·54
St Vincent and the Grenadines	712·59	848 503 505	119·07

Table 5. The costs of meeting full wastewater treatment

5.5 Social challenges

The success of treated wastewater reuse is dependent on public perception, as historically wastewater reuse projects have been shot down by public disgust at the concept. This was most vividly shown in the Australian city of Toowoomba in 2006 when local activists represented by the group 'Citizens against drinking sewage' defeated plans to introduce reclaimed sources, citing health risks and emotive factors (Monks, 2014). The negative perceptions found elsewhere (Hurlimann and Dolnicar, 2010) are likely to be present in the Eastern Caribbean as well. Nonetheless, research has shown that knowledge of and information about water augmentation strategies can increase acceptance (Dolnicar and Hurlimann, 2009). Consequently, lessons learnt from successful wastewater reuse operations such as the Windhoek water management policy and direct potable reuse (DPR) in Namibia (Lahnsteiner and Lempert, 2007) must be taken into account.

6. Emerging technologies suited to the Caribbean

Esposito *et al.* (2007) stressed the importance of combining knowledge and information on effluent constituents, treatment level attained and treatment technologies employed in evaluating the suitability of reclaimed water to ensure safe and beneficial reuse into the future.

6.5.1 Grey water recycling and irrigation

In many Caribbean islands, where stringent regulations are lacking on the treatment of grey water, household wastewater is discharged directly into stormwater drains. Opportunities exist for the installation of low-cost and low-maintenance grey water treatment at the household level, which can then be used for irrigating the vegetation in small gardens. Decentralised wastewater reuse technologies can have applications in housing developments, conventional hotel complexes and resorts, including resorts in remote locations.

6.1 Direct potable reuse

Direct potable reuse, in which purified municipal wastewater is introduced into a water treatment plant intake or directly into the water distribution system, is becoming an increasingly attractive alternative to developing new water sources (Tchobanoglous *et al.*, 2011). This technology is suited to the more arid islands, such as Antigua and Barbuda or in Trinidad, where the BWWTP now discharges over 50 million litres of treated wastewater per day.

7. Potential for wastewater reuse

At the Sandals resort, about 33% of all the water consumed is used for irrigation and is fully supplied from wastewater reuse (Sandals, 2013). If wastewater was also used for toilet flushing, following the work of Hochstrat *et al.* (2005), the quantity of wastewater reuse would go up to 37%.

At the Marriott St Kitts Royal beach resort and spa all the irrigation needs, which are about 17% of total needs, are met from wastewater reuse (Chapman *et al.*, 2012). There is a surplus of 13% of wastewater produced, which could be utilised for toilet flushing (Cremona and Saliba (2013)). The current excess treated wastewater, which is available during the rainy season, can contribute to flooding on the property. If it is used for toilet flushing, the potential for flooding would be solved and 22·5% of the total needs of the resort would be met from wastewater reuse.

In Barbados, hotels and resorts are required to install their own wastewater treatment plant (WTP) and provide freshwater for golf courses. In the case of the Coral Reef Club, 100% of wastewater is reused. RWH and wastewater reuse can be complementary. The proposed Four Seasons Hotel would use part of the 540 m^3/d of treated wastewater in combination with RWH for irrigation (Inter-American Development Bank, 2011). All the toilet flushing can be met from wastewater reuse. In the case of the Sandy Lane Properties and Golf, where the volume of treated wastewater is less than the 3700 m^3 required for irrigation (Drosfoff, 2004), the shortfall can be made up from RWH.

Based on the experiences and features in the islands and after interviews with water professionals in the islands, a number of conditions were identified (Table 6) that can be used as indicators of good potential for wastewater reuse. It was agreed that a positive answer to at least ten of these would suggest that wastewater reuse can be positively considered.

Features	Answer
1. Absence of surface water	Yes/No
2. Absence of groundwater	Yes/No
3. Annual rainfall less than 1000 mm	Yes/No
4. High dependence on desalination	Yes/No
5. Wastewater collection system in place	Yes/No
6. Water supply from desalination greater than 10% total supply	Yes/No
7. Significant number of hotels treating own wastewater	Yes/No
8. Price of water to domestic customer more than US$ 2·00/m^3	Yes/No
9. Average price of water to hotel twofold higher or more than to domestic customer	Yes/No
10. Water use by the tourism sector greater than 10% of domestic demand	Yes/No
11. Adequate legislation in place	Yes/No

Table 6. Template for preliminary assessment of the potential of an island for wastewater reuse

8. Promoting water reuse in the Eastern Caribbean

Water reuse is generally driven by issues such as water scarcity and droughts, new water policies and regulations, integrated resource management, sustainable development and environmental protection (International Water Association, 2014). Petta *et al.* (2007) discussed three areas for consideration in promoting wastewater reuse: the use of pilot projects, development of policy guidelines for wastewater reuse application and capacity building programmes. These considerations are evident in the Eastern Caribbean at different levels. As shown in this paper, there are a number of successfully operated wastewater reuse systems in the hotel industry in the region.

As part of the green economy embraced by the Eastern Caribbean, the roadmaps highlight the need for new and unconventional water sources, such as wastewater reuse. The opportunities for wastewater reuse in the Caribbean can thus be seen in the context that many of the islands are following a roadmap to a green economy and are exploring grant funding to initiate wastewater reuse projects as part of green business development. For example, Antigua and Barbuda has recently embarked on a project to identify and promote best practices in wastewater disposal, conservation and reuse in its north-western tourism zone through grant funding (GEF, 2010).

9. Conclusions and recommendations

An assessment of the status of wastewater management shows that in the Eastern Caribbean municipal wastewater collection and treatment are underdeveloped, but is much better in hotel enclaves. For example, while worldwide wastewater reuse in the tourism sector is typically less than 1% of national water use globally (Grossling *et al.*, 2012), in many of the Eastern Caribbean islands it is greater than 8%. This is driven by high water demand, high water prices, growing dependence on desalination and the emergence of stricter environmental regulations.

The implementation of centralised wastewater reuse projects by Eastern Caribbean governments is not attractive at this time owing to the high initial capital costs required. Therefore, wastewater reuse should be promoted in the hotel and resorts industry or subsector.

A nexus between desalination and wastewater reuse allows the hotels and resorts sector to reduce the overall costs of water supply, overcome shortages in the dry season and meet stringent wastewater disposal requirements.

Wastewater reuse can meet up to 38% of the needs of major hotels and resorts if it is employed for irrigation and toilet flushing. The potential and the opportunities for wastewater reuse are enhanced where hotels are in a close cluster, such that all the wastewater can be directed to a central treatment facility and utilised as required within the cluster.

The hotel industry should focus on wastewater reuse as a way to guard against higher costs or diminished water supply. Governments can also promote the reuse of wastewater by developing adequate regulations and providing incentives.

The promotion of household wastewater reuse under hygienic conditions by the provision of appropriate education and technology support is recommended.

Wastewater reuse systems developed for irrigation should be designed such that adequate consideration is given to excess water during the rainy season.

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