Wastewater and Biosolids/Sewage Sludge Reuse in the Wider Caribbean Region

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A report prepared by

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Introduction

The Global Environment Facility-funded Caribbean Regional Fund for Wastewater Management (GEF CReW) is a four-year project that began in 2011, extended for an additional 18 months with an end-date of January 2017. Implemented by the Inter-American Development Bank (IDB) and the United Nations Environment Programme (UNEP), it is an integrated and innovative approach to reducing the negative environmental and human health impacts of untreated wastewater discharges in the Wider Caribbean Region (WCR).

Regional governments have long recognized that land-based sources of pollution from municipal, industrial and agricultural sectors and their negative impacts on marine resources are a threat to the region's economic development and the quality of life of its people. Further, they acknowledge that untreated sewage is one of the major threats to public health and the environment in the Region and is the result of rapidly expanding urban populations, poorly planned development, and inadequate or poorly designed and malfunctioning sewage treatment facilities.

In 1999, governments of the WCR signalled their commitment to reduce marine pollution from untreated wastewater by agreeing to the Protocol on the Control of Land Based Sources of Marine Pollution (LBS Protocol). The LBS Protocol forms part of the only legally binding regional agreement for the protection and development of the Caribbean Sea – the Cartagena Convention. Its entry into force in 2010 committed the Governments which ratified or acceded to it to making major improvements in wastewater management by introducing innovative and cost effective treatment technologies, improving the policy, regulatory and institutional frameworks, and expanding access to affordable financing.

However, UNEP GPA reported in their 2006 State of the Marine Environment Report that significant financial constraints exist: there is a lack of adequate, affordable financing available for investments in wastewater management in the WCR. Smaller communities in particular often find it difficult to obtain affordable financing for such improvements. Therefore, developing innovative financial mechanisms and making affordable resources available to assist countries in the WCR to establish or expand domestic wastewater management programs and policies, based on national and local community needs, constitutes a priority for the region.

This was the impetus for the establishment of the GEF CReW project. The project’s overarching aim is to provide the way forward for financing of the wastewater sector within a policy and legal framework which will support sustainability. The GEF CReW project has three interlinked components: 1) Investment and Sustainable Financing – testing individual Pilot Financing Mechanisms in four of the participating countries: Belize, Guyana, Jamaica and Trinidad & Tobago; 2) Reforms for Wastewater Management – addressing key capacity constraints within legal, institutional and policy frameworks; and 3) Communications, Outreach and Training.

As shown in Figure 1, the 13 countries that are participating in GEF CReW are: Antigua & Barbuda, Barbados, Belize, Costa Rica, Guatemala, Guyana, Jamaica, Honduras, Panama, Saint Lucia, Saint Vincent & the Grenadines, Suriname, and Trinidad & Tobago.

Figure 1: CReW Participating Countries

Source: CReW 2014.

Achievements of GEF CReW include – among others:

- Pilot Financing Mechanisms for wastewater management were established in three countries (Belize, Guyana and Jamaica) and are providing funding for first generation projects.
- Participating countries have initiated national wastewater planning activities such as development of national action plans, creation of national inter-ministerial committees, harmonization of regulations and legislation, development of wastewater treatment and reuse legislative instruments, and adoption of new wastewater and sludge regulations.
- Customized wastewater management training programmes, designed and implemented with partners such as CDB, UNITAR, World Bank and the Water Center, have been delivered both in person and online to more than 600 persons and some programmes are being instutionalized within national training institutions.

Significantly, CReW's activities have resulted in better understanding of the need for good wastewater management, with several countries reporting that wastewater is more present on the national agenda than before. There is clear evidence of high level government commitment to more investment and support for wastewater management. Seven CReW countries have ratified the LBS Protocol[1] and several others have initiated national discussions on LBS Protocol ratification using wastewater as the main pollution area of concern.

CReW countries that have ratified the LBS Protocol

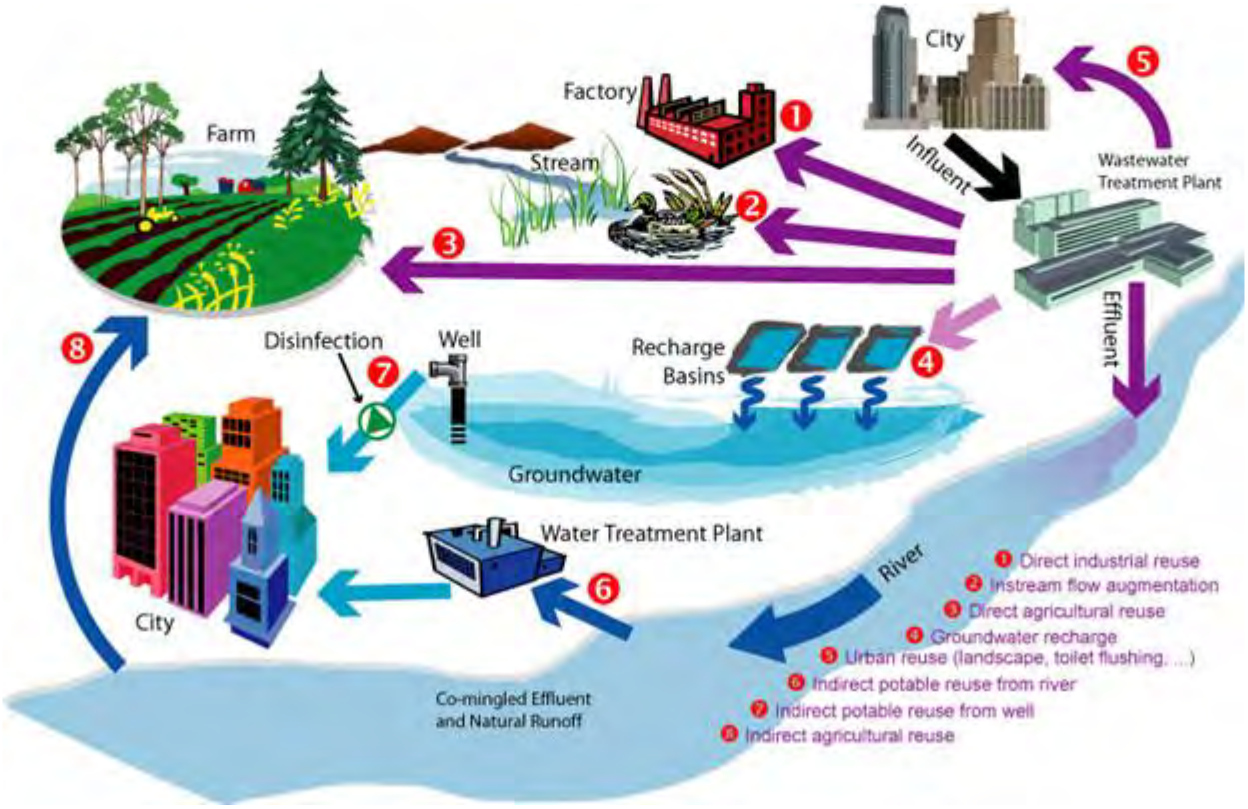
Antigua and Barbuda
Belize
Guyana
Jamaica
Panama
Saint Lucia
Trinidad and Tobago

[1] http://www.cep.unep.org/cartagena-convention/ratification-lbs.png/view

Through CReW, the countries of the Wider Caribbean Region have learned much about how to improve wastewater management effectively and have been alerted to the potential of "wastewater as a resource". This report explores the use of sanitation waste – wastewater and sewage sludge – as a resource within the Region. Specifically, the report describes wastewater and biosolids/sewage sludge reuse in WCR countries; presents existing regional guidelines/criteria that can or should be used in the reuse of treated wastewater and biosolids/sewage sludge; and provides examples of applications from outside of the Caribbean which might be replicated in the region.

Source: United Nations University

Sanitation Waste as a Resource



Using treated sanitation waste as a valuable resource has increasing viability and acceptance worldwide and is an opportunity to attract interest and investment in sewage and wastewater management by both the public and private sectors. This increased investment will reduce and the negative impacts of improperly treated sanitation waste on people and ecosystems. At the same time, value can be obtained from the water, nutrients, organic matter and energy contained in sanitation and other wastewater and organic waste streams. These resources should be safely recovered and productively reused.

The opportunity for this resource recovery is vast. Globally, countries produce an estimated 9.5 million m^3 of human excreta[2] and 900 million m^3 of municipal wastewater every day (Andersson et al 2016). This waste contains enough nutrients to replace 25 per cent of the nitrogen currently used to fertilize agricultural land in the form of synthetic fertilizers, and 15 per cent of the phosphorus, along with enough water to irrigate 15 per cent of all the currently irrigated farmland in the world.

Furthermore, the 2013 study — "Global, Regional, and Country-level Need for Data on Wastewater Generation, Treatment, and Use", found that water demands already exceed supplies in regions with more than 40 per cent of the world's population, and in 12 years the spectre of water scarcity could confront up to 60 per cent of the world population (UNU 2013).

[2] Based on 1.3 litres of excreta per person and a world population of 7.3 billion people

Based on the limited data on wastewater treatment available, the study found that, on average, high-income countries treat 70 per cent of their generated wastewater. Upper-middle-income and lower-middle-income countries treat 38 per cent and 28 per cent of their generated wastewater, respectively, while lower-middle-income countries treat just 8 per cent. However, in North America, although 75 of generated wastewater is treated, only 3.8 per cent is used.

The concept of "sustainable sanitation" promoted by the Sustainable Sanitation Alliance (SuSanA) encapsulates this holistic approach to meet people's needs for safe sanitation while reducing impacts on the environment and conserving natural resources (Andersson et al 2016).

> Sustainable sanitation and waste-water management systems are those that minimize depletion of the resource base, protect and promote human health, minimize environmental degradation, are technically and institutionally appropriate, socially acceptable and economically viable in the long term.
>
> They should both be sustained – used by target population while functioning properly over the long term, as well as resilient to disasters – and contribute to broader socio-economic and environmental sustainability.
>
> *- SuSanA*

Increased water availability, through safe reuse of treated effluent, can lead to numerous opportunities in almost every sector. Wastewater can be recycled or reused for many activities that demand water such as agriculture, aquifer recharge, aquaculture, firefighting, flushing of toilets, industrial cooling, park and golf course watering, formation of wetlands for wildlife habitats, and several other non-potable requirements. It may be possible also to produce drinking water from adequately treated wastewater. Treated effluent can be a source of water and nutrients that can be used for crop production, reducing the need for scarce freshwater and expensive fertilizers, and can increase crop yields at a reduced cost to farmers. Aquaculture may provide additional economic opportunities in developing countries. Nutrients found in wastewater discharges that normally pollute the environment are beneficial when used with irrigation and aquaculture applications. Wastewater sludge can be used as fertilizer, to manufacture construction materials and to generate biogas and biofuels.

Figure 2 below shows some examples of ways to reuse components of sanitation waste as well as municipal and agricultural waste. It effectively shows how the "waste challenge" can be turned into an opportunity. Some of the world's most pressing problems of water, food and energy security can be ameliorated through "waste as a resource" initiatives. While a comprehensive "waste as a resource" plan should include solid waste and agricultural waste reuse, this report focuses on reuse of sanitation waste – wastewater and biosolids/sewage sludge – in the Wider Caribbean Region.

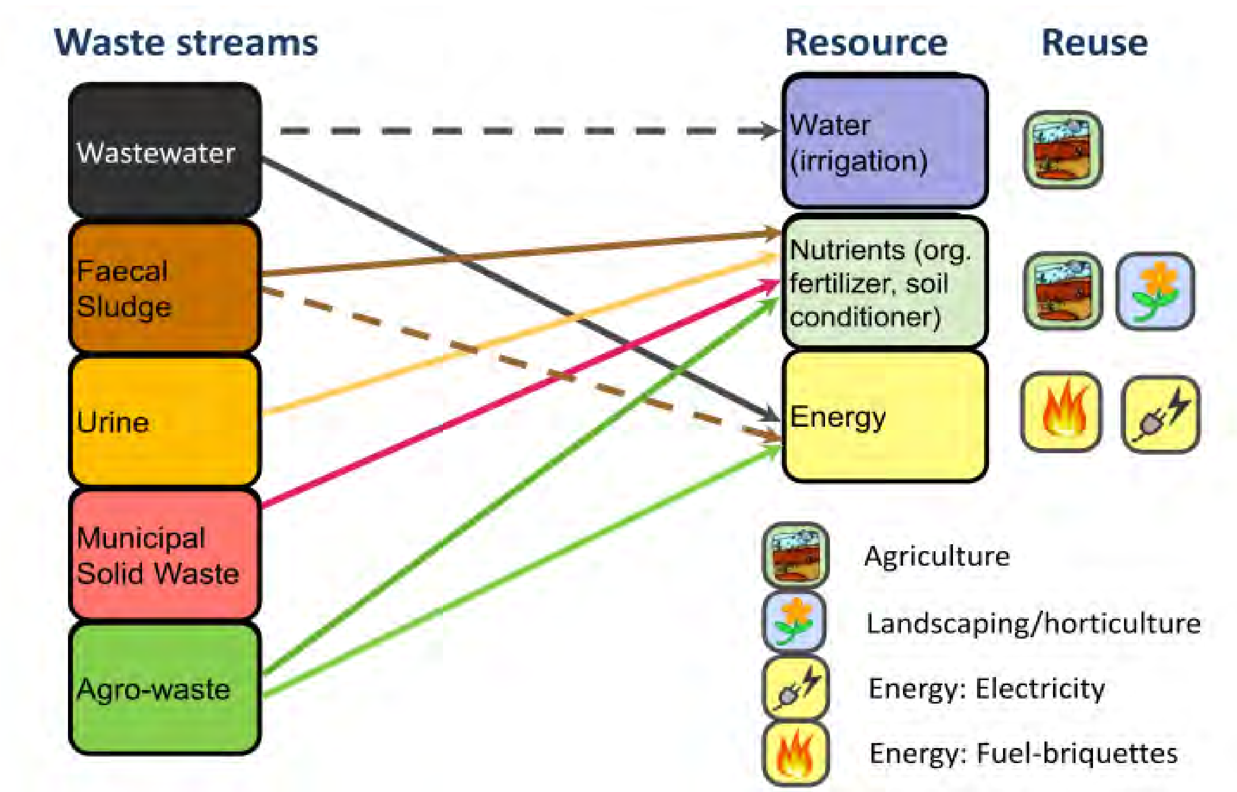


Figure 2: Changing the waste challenge into an opportunity
Source: Gebrezgabher and Taron, 2015

Wastewater and Biosolids/Sewage Sludge Reuse – Some Basics

Sanitation waste products include wastewater as well as waste from dry sanitation systems. Wastewater treatment facilities produce a liquid effluent, which is discharged to water bodies or reused. The quality of the effluent will depend on the level of treatment used by the facility. Wastewater is treated to three levels, namely primary, secondary and tertiary levels. As a byproduct of the treatment process, facilities also produce solid residues (sewage sludge) that, with further treatment, can yield biosolids. Table 1 presents definitions of the key terms related to wastewater and sludge reuse.

Table 1: Key Terms Related to Wastewater and Sludge Reuse

Term/Concept	Definition
Wastewater	A combination of one or more of: domestic effluent consisting of blackwater and greywater; water from commercial establishments and institutions, including hospitals; industrial effluent, storm water and other urban run-off; agricultural, horticultural and aquaculture effluent. It is any water that has been adversely affected in quality by human activities and can contain dissolved and/or suspended pollutants. It may contain pollutants such as nutrients, pathogens and viruses.

Term/Concept	Definition
Water reuse **Wastewater reuse** **Water recycling** **Wastewater recycling**	Using treated wastewater for a beneficial purpose
Water reclamation	The process of treating wastewater prior to reuse
Blackwater	Excreta, urine and faecal sludge
Greywater	Untreated household waste water which has not come into contact with toilet waste (e.g. used water from bathtubs, showers, bathroom wash basins, kitchens and water from clothes-washers and laundry tubs)
Sludge / sewage sludge	A solid, semi-solid or liquid residue generated during the treatment of domestic sewage in a treatment plant and includes but is not limited to domestic septage, scum or solids removed in primary, secondary or advanced wastewater treatment processes[3]
Biosolids	Nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility. When treated and processed, these residuals can be recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth.[4] ***Biosolids are treated sewage sludge. Biosolids are carefully treated and monitored and must be used in accordance with regulatory requirements.***
Septage	The liquid or solid removed from a septic tank, or solid removed from a septic tank, cesspool or portable toilet
Sewage	Liquid and solid waste carried off in sewers or drains
Sewerage	The entire system of sewage collection, treatment, and disposal
Effluent	The outflow of treated or untreated wastewater from a sewage treatment facility or a domestic, commercial or industrial facility
Disinfection	The killing of harmful bacteria in sewage – usually by chlorine, but increasingly by exposure to ultraviolet radiation
Suspended solids	Solid materials floating in wastewater (physical particles that can clog rivers or channels as they settle under gravity)
BOD	Biochemical Oxygen Demand - the rate at which organisms use the oxygen in water or wastewater while decomposing organic matter under aerobic conditions. BOD measurements are used as an indicator of how much organic material is in the water/wastewater
Primary sewage treatment	Removal of floating and suspended solids which make up about 30 - 35 per cent of pollutants that must be removed

[3] As defined in the Jamaica Natural Resources Conservation (Wastewater and Sludge) Regulations
[4] As defined by the United States Environmental Protection Agency - https://www.epa.gov/biosolids/frequent-questions-about-biosolids

Term/Concept	Definition
Secondary sewage treatment	Removal of dissolved and suspended biological matter, reducing the level of suspended solids and BOD
Tertiary sewage treatment	Removal of all but a negligible portion of bacterial and organic matter

Benefits of Reusing Sanitation Waste

The main benefits of reusing treated sanitation waste are described below.

Agricultural productivity and soil quality

Residential and agricultural wastewater and sanitation waste contains large amounts of the three most important and economically valuable inputs for agriculture: nutrients, organic matter and water. With appropriate treatment of wastewater or excreta, these can all be recovered and safely reused by farmers. Using wastewater as a source of water and nutrients can facilitate aquaculture and the production of non-traditional high value crops such as flowers.

Clean energy and climate mitigation

Organic waste produces methane when it decomposes. Methane is a greenhouse gas (GHG) more than 25 times as potent as carbon dioxide (CO_2). Capturing the energy content of wastewater and excreta can be an efficient way to produce renewable energy, as well as an effective climate mitigation measure. Improved sanitation and wastewater management reduce emissions of several key GHGs, primarily CO_2, methane, and nitrous oxide.

Green business and employment opportunities

There are economic beneficiaries and employment opportunities along almost any wastewater management and sanitation value chain, including construction, operation and maintenance, transport, and treatment. Recovery and reuse add many more potential direct and indirect beneficiaries: farmers, transporters, vendors, processors, inputs suppliers and consumers. Harvesting of biomass grown within wastewater treatment systems can be used as feed for on-site aquaculture or sold for animal husbandry to provide an additional income stream for the plant, adding to the financial stability and sustainability of the treatment systems. Also, faecal sludge management – emptying pits and septic tanks, transporting the sludge and treating it – is an area of growing business interest. It has proved to have strong market potential in many cities in which it is common to rely on pit latrines and other on-site systems.

Water security

Water security is a growing problem for many arid and semi-arid areas, and those where demand from industry, energy generation, agriculture, freshwater supply and ecosystem replenishment is greater than availability. Making the water portion of wastewater available for safe reuse or environmental release can relieve these pressures. Reusing treated water increases the supply of available water and reduces the diversion of water from alternative uses, including supporting ecosystem services. Recycling and reuse of wastewater reduces and eliminates discharges of both treated and untreated wastewater into waterways, water bodies and the coastal environment. The role of wastewater reuse in water security is explored further within the context of integrated water resource management below.

Integrated Water Resource Management

Integrated water resource management (IWRM) addresses competing claims for water for municipal, industrial and agriculture use. In many countries, water resource managers and planners are continually looking for additional sources of water to supplement the limited resources available in their country and recognize that wastewater could be considered as a renewable resource within the hydrological cycle – as shown in Figure 3.

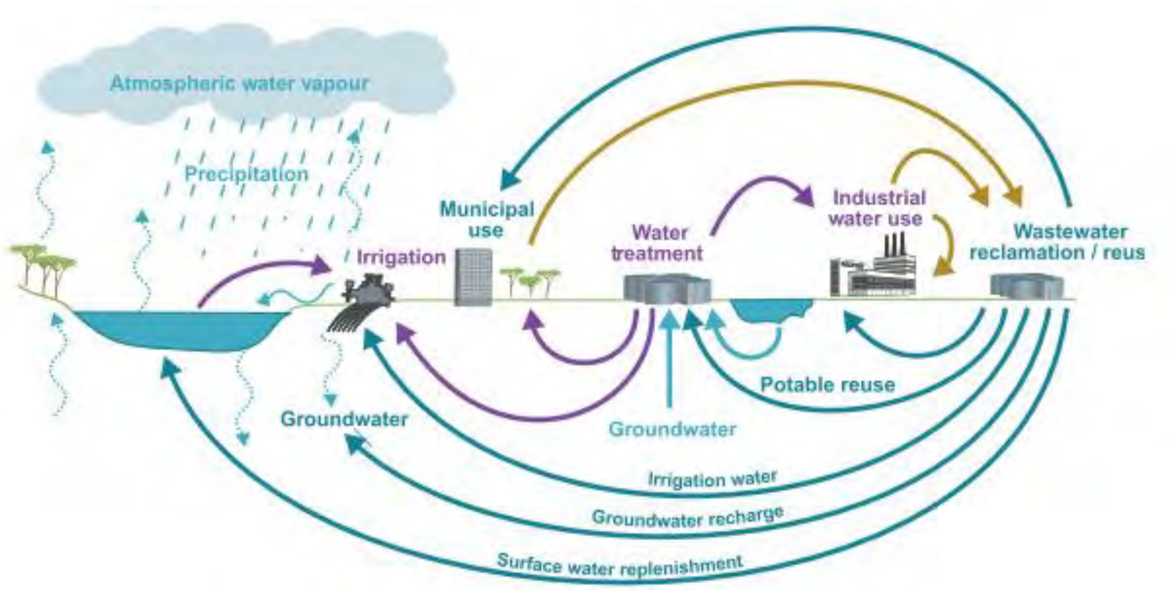


Figure 3: Wastewater reuse as part of the water cycle
Source: Andersson et al 2016.

There are two main types of water reuse projects: non-potable and potable. Beneficial non-potable uses of wastewater include:

- Urban – for fire protection, construction, air conditioning, and aesthetic purposes, e.g. ornamental landscapes and decorative water features, such as fountains, reflecting pools and waterfalls
- Recreation – irrigation of public parks, golf courses, recreation centres, athletic fields, school yards and playing fields; swimming, boating, fishing
- Aquaculture
- Irrigation – agriculture, public parks, playgrounds and residences, landscaped areas surrounding public, residential, commercial and industrial buildings
- Industrial – including evaporative, process and boiler feed water, fire protection, toilet and urinal flushing in commercial and industrial buildings
- Residential – toilet and urinal flushing, gardens, fed from domestic wastewater

- Environmental – environmental flows to build or replenish wetlands or stabilize other ecosystems and for groundwater recharge (e.g. by "topping up" aquifers) to increase freshwater supplies
- Recreational/tourism – creation of recreational lakes, protection of marine water quality

Potable reuse projects use highly treated reclaimed wastewater to augment a water supply that is used for drinking and all other purposes. Non-potable options are less costly as they mostly involve less treatment. Reuse in agriculture has the added benefit of reusing the nutrients existing in wastewater and hence reducing the demand on commercial fertilizer. The constraints to using wastewater (non-potable reuse) are usually related to the high costs involved in the construction of dual water distribution networks, operational difficulties and the potential risk of cross-connection. However, costs should be balanced with the benefits of conserving drinking water and eventually of postponing, or eliminating the need for the development of new sources of water or the expansion of existing water supply networks.

Ensuring Water Quality

Modern technology makes reclaimed water safe for many beneficial purposes. Analyses have shown that carefully planned potable water reuse projects can provide a level of protection from waterborne illness and chemical contaminants comparable to and, in some cases, better than the level of protection the public experiences in many drinking water supplies (NRC 2012).

Major wastewater contaminants include (NRC 2012):

- **Pathogens**. Bacteria, viruses, and other infectious organisms enter wastewater from human excrement and other waste. Viruses with the potential to cause disease are of particular concern for potable reuse because they are very small, can be difficult to eliminate from water, and some can cause infection even at low concentrations.
- **Nutrients**. Municipal wastewaters are rich in nitrogen and phosphorus. Some forms of nitrogen can present a health risk for potable reuse if not properly treated. Excess nutrients can also cause the overgrowth of algae when reclaimed water is used to augment lakes. On the other hand, some non-potable uses, such as irrigation, are actually enhanced by higher nutrient levels.
- **Organic chemicals**. Pharmaceuticals, natural hormones, household chemicals, and byproducts formed during the treatment process are often present in wastewater. High levels of such chemicals could pose a health risk, particularly for potable uses, unless they are effectively removed or degraded by appropriate water treatment processes.
- **Other contaminants**. Metals and salts are examples of other contaminants that could affect drinking water taste or pose a risk for human health and the environment.

It is critical that adequate health safeguards are implemented regarding wastewater and sludge treatment, crop restriction, appropriate application methods and human exposure control. The World Health Organization (WHO) Health Guidelines for the use of wastewater, excreta and greywater[5] should be consulted to ensure that any reuse of wastewater is safe for those who use reused wastewater and those who directly consume food products grown with reused wastewater. (i.e. eating contaminated crops or eating animals that have fed on contaminated crops or developed in wastewater ponds).

Table 2 shows the advantages and possible risks of different types of reuse. These uses will typically require different standards and criteria based on the different risks and accompanying issues.

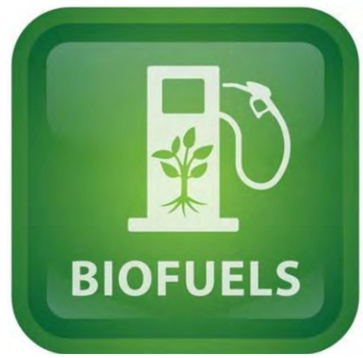
Table 2: Advantages and possible risks or constraints for different reuse options

Reuse option	Advantages	Possible risks and constraints
Irrigation	• highest demand for water • nutrients recycling • fertilizer use reduced • well established	• surplus nutrients might reach groundwater • storage systems needed • clogging of irrigation systems • high hygiene requirements • soil salinization • crop damage
Industrial	• cost-saving • recycling of wastewater constituents	• corrosion or fouling • aerosol transmission • additional treatment needed
Environmental	• habitat creation / conservation	• additional treatment needed
Aquifer recharge	• natural biodegradation and filtration • high removal rates with soil aquifer treatment • limited treatment requirements	• groundwater contamination • interactions of reclaimed water and groundwater • specific hydrogeological requirements

[5] http://www.who.int/water_sanitation_health/wastewater/gsuww/en/

The Context for Reuse of Sanitation Waste in the Wider Caribbean Region

As noted above, in addition to improving sanitation and wastewater management in the Wider Caribbean Region, recycling and reusing sanitation waste has vast potential to benefit the **water**, **agriculture** and **energy** sectors in the Region. The demand by these sectors for the products of sanitation waste reuse will factor into decisions about the types of reuse projects to implement.



Water Supply and Demand

The region as a whole has made significant progress in water supply and most countries report over 95 per cent access to improved water supplies. Problems are primarily associated with the quality of service, maintenance and operation of existing infrastructure, ageing infrastructure, and high levels of unaccounted for water, as well as concerns over potable water quality.

The rainfall and freshwater availability in WCR countries vary considerably. In the islands of the Eastern Caribbean, there is high rainfall averaging over 2,000 mm annually, whereas in Antigua and Barbuda and some of the other small islands, average annual rainfall is less than 1,000 mm (Peters 2015). There are even variations within small island nations; 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. Jamaica's average annual rainfall is relatively low at 1,270 mm whereas Trinidad & Tobago's average is 2,000 mm – with a high of 3,800 mm in some mountainous areas. In Central American CReW countries, annual rainfall figures range from 1,316 mm in Guatemala to approximately 3,200 mm in Panama. In Belize, annual rainfall ranges from 1,524 mm in the north to 4,064 mm in the south (worldweatheronline). At the highest extreme, some mountainous areas in Costa Rica receive as much as 7,600 mm of rainfall per year.

In addition to rainfall, the water supply and the importance of each source varies among countries. 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 rainwater harvesting (Peters 2015). Most countries in the region depend on surface waters. The percentage of the "Total Actual Renewable Water Resources" (TARWR) that is from surface waters ranges from 59 per cent in Jamaica to 100 per cent in Guyana (AQUASTAT, FAO 2005). However, many countries are dependent on groundwater sources, some of which overlap[6] with surface water. For example, 43 per cent of Guyana's TARWR comes from groundwater, overlapping with the water available from surface waters. In some countries such as Jamaica – there is no overlap; the remaining 41 per cent of TARWR comes from groundwater. Additionally, in countries with distinct wet and dry 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 per cent respectively in the dry season and 25, 15 and 60 per cent respectively in the rainy season (Peters 2015).

The long-term availability of freshwater is of concern. Given increasing levels of demand and expected changes in rainfall patterns brought on by climate change, even a slight reduction in rainfall would have serious consequences. There is already a gap between the ability to supply and the level of demand in many Caribbean countries. Barbados is using close to 100 per cent of its available water resources, Saint Lucia has a 35 per cent water supply deficit and Trinidad and Tobago has had a deficit since 2000 (GWP 2014). Jamaica is projected to experience deficits in areas of important economic activity by 2015, Antigua and Barbuda is reliant on desalination to meet demands, while in Dominica, Grenada, and St. Vincent and the Grenadines demand can exceed supply during the dry season as a result of reduced stream flows.

The situation is compounded by high levels of unaccounted for water (for example, 67 per cent in Jamaica, 40 per cent in Trinidad and Tobago, and 50 per cent in Barbados) (Janson 2014). Even though many of these countries have sufficient water resources to meet demand, they do not have the infrastructure or institutional frameworks to supply the demand. It is only in some of the drier islands, such as Antigua and Barbuda, Barbados and The Bahamas, that the water resources can truly be considered scarce.

Groundwater aquifer yields are threatened by prolonged periods of low rainfall and abstraction levels that exceed the sustainable long-term aquifer recharge. This is especially the case for coastal aquifers where abstractions have resulted in increased levels of salinity. High concentrations of nitrates observed in abstractions from the Liguanea aquifer in Kingston and St Andrew, Jamaica and the Belle area, Barbados have been attributed to inappropriate sewage disposal in urban areas (GWP 2014), making the contaminated groundwater unusable.

The distribution of the demand for water depends on the composition of countries' economies. On a global level, agriculture is by far the largest consumer of available freshwater: 70 per cent of "blue water" withdrawals from watercourses and groundwater are for agricultural usage[7]. Most countries in the WCR depend on two water-intensive industries: agriculture and tourism.

[6] Overlap is water shared by both the surface water and groundwater systems.
[7] http://www.globalagriculture.org/report-topics/water.html

Notable exceptions are Panama, Suriname and Trinidad and Tobago. Table 3 shows the contribution of various sectors to national GDP in CReW participating countries.

Table 3: Contribution of Economic Sectors towards GDP

Country	% Contribution to GDP		
	Agriculture[8]	Tourism[9]	Other[10]
Antigua and Barbuda	2.3 Labour – 7.0	57.1	
Barbados	2.8 Labour – 10.0	39.5	
Belize	12.7 Labour – 10.2	38.6	
Costa Rica	5.6 Labour – 14.0	12.6	Technology services
Guatemala	13.6 Labour – 31.0	8.9	
Guyana	20.7 Labour – N/A	8.2	Sugar, gold, bauxite, shrimp, timber, and rice account for nearly 60% of GDP
Honduras	13.9 Labour – 39.2	15.1	
Jamaica	6.6 Labour – 17.0	29.3	
Panama	2.8 Labour – 17.0	18.3	Services account for more than 75% of GDP (operating the Panama Canal, logistics, banking, the Colon Free Trade Zone, insurance, container ports, flagship registry and tourism)
Saint Lucia	2.9 Labour – 21.7	41.5	
St. Vincent and the Grenadines	7.9 Labour – 26.0	23.2	
Suriname	6.4 Labour – 11.2	2.9	Exports of oil, gold, and alumina accounts for about 85% of exports and 27% of government revenues
Trinidad and Tobago	0.5 Labour – 3.6	8.5	Oil and gas account for about 40% of GDP

Agriculture is an important sector in many WCR countries despite the economic diversification which has taken place over the last several decades, with the growth of service industries, notably tourism and financial services. As shown in Table 3, the agriculture sector's contribution

[8] From CIA World FactBook: https://www.cia.gov/library/publications/the-world-factbook/
[9] From World Data Atlas: https://knoema.com/atlas/topics/Tourism/Travel-and-Tourism-Direct-Contribution-to-GDP/Direct-Contribution-to-GDP-percent-share
[10] From CIA World FactBook: https://www.cia.gov/library/publications/the-world-factbook/

to GDP among CReW participating countries range from a high of 20.7 per cent in Guyana to a low of 0.5 per cent in Trinidad and Tobago.

However, the agriculture sector's share of the labour force is even more important than its contribution to GDP as shown in Table 3. Approximately one third of the labour force in Honduras, Guatemala and probably Guyana is engaged in agriculture. Furthermore, the agriculture sector makes an important contribution to rural development in the region.

The tourism industry's contribution is greatest in Antigua and Barbuda and Saint Lucia and lowest in Suriname and Trinidad and Tobago, which depend on other industries (mining and oil/gas respectively) and Panama, which has a diversified services sector that includes but is not greatly dependent on tourism.

Water demand varies among WCR countries but in most countries is dominated by the agriculture (for irrigation) and/or tourism sectors (e.g. for landscaping, water parks, swimming pools and golf courses).[11] Statistics related to water use in the tourism sector are difficult to find. Peters (2015) reports that in Barbados and Jamaica, it was estimated that the tourism sector consumes 16.6 per cent and 14.2 per cent of total water respectively. Peters' estimates for water consumption by the tourism sector in certain Caribbean countries range from 7.6 per cent (Dominica) and 20.2 per cent (Antigua). Per capita water use in tourism has been estimated at between 1.5 to 2.5 times the domestic use per capita (Peters 2015). This may lead to increasing competition between domestic and tourism demands and must be factored into water resource management.

Despite the agriculture sector's lower contribution to GDP, agriculture uses on average 63 per cent of water in the Caribbean and Central America (FAO 2014). Among WCR countries, Trinidad and Tobago and Antigua and Barbuda use 4 per cent and 12 per cent for agriculture, respectively but most other countries use more than 50 per cent of its water supply for agriculture. In Guyana the portion is an extraordinary 87 per cent.

The Agriculture Industry

As discussed above, the agriculture sector provides a major opportunity for wastewater reuse to meet the large demand for irrigation water. However, biosolids/sewage sludge from wastewater treatment processes and other solid sanitation waste can also be used as soil conditioners and fertilizers.

Recycled sanitation waste products (liquid and solid) can help to address the following challenges experienced by the agriculture sector in the WCR:

- Poor land and soil quality due to poor management and utilization of the natural environment
- Vulnerability to natural hazards and climate variability – hurricanes and storms, severe rainfall as well as droughts

[11] These two sectors also generate large volumes of wastewater.

- High consumption of water and dependence on irrigation
- High dependence on chemical fertilizers

Energy

All CARICOM Member States depend heavily on fossil fuels to supply their energy demand, which in almost all cases is imported. Only one country, Trinidad and Tobago, is a major producer and only net exporter of petroleum, petroleum related products and natural gas. In 2005 Suriname exported some amount of crude oil but imported liquefied petroleum gas, gasoline and diesel oil.

The contribution of renewable energy in CARICOM is small compared to the vast potential available. Renewable energy contributed about 9 per cent to the total primary energy consumed between 1998 and 2007 (mainly from hydropower, solar and wind). Belize, Jamaica and Suriname recorded significant increases in renewable energy electricity mainly from hydropower. However, there is biomass-based energy notably in Belize, Guyana and Suriname (CARICOM, 2013).

Countries in the region are increasing the contribution of renewable energy to their energy mix in attempt at increasing energy security and reducing costs. While the best developed options are in solar, hydropower and wind energy, there is increasing focus on energy from waste and biofuels. For example, in Jamaica there are two national energy policies that specifically target these two areas. While energy-from-waste initiatives generally target solid municipal and industrial waste, there is room for inclusion of sanitation waste such as sludge.

Wastewater Management

According to the Joint Monitoring Program (JMP) of UNICEF and the World Health Organization (2015), in Latin America and the Caribbean in 2015, 83 per cent of the population had access to improved sanitation – an increase from 67 per cent in 1990 (see Box 1 below for a definition of an "improved sanitation" facility). In 2015, 106 million people in Latin America and the Caribbean lived without access to an improved sanitation facility. There continues to be a sharp division between urban and rural homes in their sanitation facilities.

As shown in Box 1, "improved sanitation" includes facilities that are connected to sewers and septic tanks. According to the JMP 2008 report, of the 77 per

Box 1

Improved sanitation facilities are defined as facilities that ensure hygienic separation of human excreta from human contact.

They include:

- connection to a public sewer
- connection to a septic system
- pour/flush latrine
- simple pit latrine
- ventilated improved pit latrine

They do not include:

- public or shared latrine
- open pit latrine
- bucket latrines

- JMP Joint Monitoring Programme for Water supply & Sanitation

cent of the population in Latin America and the Caribbean that had access to sanitation, 51 per cent of households were connected to a sewer and 26 per cent to septic tanks and various types of latrines.[12] Therefore, in 2008, 39 per cent of the population in these regions was connected to a sewerage system.

While there is demonstrated progress, sanitation in the Wider Caribbean Region is still characterized by insufficient access, particularly in rural areas, poor service quality in some areas and inadequate treatment of sanitation waste from these facilities. The wastewater sector in the WCR is generally characterized by insufficient, inefficient and technically inadequate wastewater treatment plants.

For example, in Jamaica, the quality of effluent treatment in Jamaica is mostly poor – a study of the performance of the Jamaican domestic wastewater sector conducted from 2001 to 2003, showed that only 40 per cent of the 60 plants monitored met the national effluent standards (UNEP 2014). Many of the existing septic systems are located in limestone and not functioning properly and as such only partially treat the raw sewage and grey water. This results in direct environmental impacts that can immediately contaminate any nearby water body such as creeks, rivers, sea and groundwater. Similar – or worse – situations exist on other WCR countries.

However, WCR governments have indicated their commitment to improving wastewater management, for example, by ratification of the LBS Protocol. Governments and wastewater utilities have made recent commitments to improving the wastewater sector through investments in sewage treatment plants and increased focus on the legal, regulatory and institutional frameworks. Also, countries have made progress in improving compliance with and of monitoring effluent standards (Janson 2014).

All WCR countries have a range of laws that govern environmental protection (including pollution) as well as responsibility for the water and wastewater sector. However, there is generally a lack of coordination among various pieces of legislation, which are of varying ages. Additionally, in most countries there is inadequate enforcement of existing laws, a lack of water quality and effluent standards and insufficient water quality monitoring.

[12] http://www.cep.unep.org/publications-and-resources/marine-and-coastal-issues-links/wastewater-sewage-and-sanitation

Wastewater and Biosolids/Sewage Sludge Reuse in the Wider Caribbean Region

Wastewater – treated and untreated – is frequently used to irrigate agricultural lands in WCR countries. This occurs mainly because it is the only water source available for irrigation year-round, wastewater irrigation reduces the need for purchasing fertilizer, and wastewater irrigation involves less energy cost if the alternative clean water source is deep groundwater. Also wastewater enables farmers in urban areas to produce high-value vegetables for sale in local markets.

It is likely that the demand for wastewater as a source of irrigation will increase at a faster pace than the development of technical solutions and institutions that might ensure the safe distribution and management of wastewater. Thus, the key technical and policy questions in developing countries include those pertaining to better methods for handling untreated wastewater on farms and in farm communities, better recommendations regarding the crops and cultural practices most suitable for settings in which wastewater is the primary source of irrigation, better methods for protecting farm workers and consumers from the potentially harmful pathogens and chemicals in wastewater, and capacity development of relevant professionals to tackle the complex issues arising from the agricultural use of wastewater.

In many countries, existing legislation aims to place controls on already occurring reuse of wastewater – mainly in agriculture – rather than to promote new planned reuse initiatives. Wastewater discharge regulations control reuse for agricultural irrigation because untreated wastewater is often used to irrigate crops. Overall, the aim of wastewater reuse guidelines is to protect the population from health risks and the environment from degradation and pollution. Most of the worldwide available guidelines are based on either the US Environmental Protection Agency (EPA) guidelines or the 2006 WHO guidelines. These guidelines are suitable for developed countries with high wastewater treatment standards, but should be adjusted for countries in the WCR.

Table 3 presents a summary of the wastewater management environment, relevant legislation and some examples of sanitation waste reuse within the CReW participating countries. Table 3 includes only the legislation and regulations that are the most pertinent to sanitation and wastewater management and reuse of sanitation waste.

Table 3: Wastewater and Sludge Reuse in the Wider Caribbean Region

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
Antigua and Barbuda	The country lacks adequate domestic handling and holding facilities within St. John, treatment facilities prior to discharge, and appropriate waste disposal mechanisms for septic tank sludge. There is no central sewer system and several types of individual systems are used - the bucket system (night soil system), pit privies, septic tanks and soak-a-ways, and sewage package plants. The majority of the hotels and some businesses employ sewage package plants but a survey in 1994 by the Pan American Health Organization (PAHO) revealed that 88 per cent of these plants are not functioning properly, operating above national effluent limitations.	The water quality guidelines, were proposed in 2008 to ensure that water quality on the island is maintained. The guidelines recommend a licensing regime that requires hotels and wastewater industrial agencies to apply and receive permits to discharge effluents in coastal areas. However, there is no proper enforcement system for ensuring compliance with any standards. A recent national IWRM policy focuses on integrating strategies and activities to improve water, wastewater, land management, and disaster preparedness – in all sectors.	Incentives exist for reusing wastewater due to the high cost of desalinization which provides 70 per cent of Antigua and Barbuda's water. Most hotels with 50 or more rooms have on-site wastewater treatment plants and reuse wastewater for irrigation. One large hotel recycles approximately 68 per cent of its daily water consumption, using it for irrigation. As part of the national IWRM focus, a demonstration project was implemented to address the impact of sewage overflows from septic tanks on an important coastal wildlife area. The intervention included household connections to a new sewage treatment plant that will use treated effluent to irrigate local farms.
Barbados	Barbados is serviced by two municipal sewage treatment systems, which discharge directly to the marine environment. Pit latrines are used in Barbados as the most common means for the disposal of human faeces, grey (kitchen and bath) water and storm water. The majority of the hotels	The Marine Pollution Control Act 2000 requires all discharges to comply with new discharge limits as outlined on the draft Marine Pollution Control (Discharge) Regulations.	In Barbados, hotels and resorts are required to install their own wastewater treatment plant and many recycle the wastewater to provide water for golf courses and gardens. The Coral Reef Club reuses

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
	and some business places employ the use of sewage package plants. Seventy per cent of plants surveyed in 2005 met the discharge standards. Overall, less than 10 per cent of the island's generated wastewater is being collected in a way that allows it to be treated for reuse.	A draft Wastewater Reuse Act and Water Reuse Concept Plan have been developed.[13] In 2013, Barbados began developing standards for wastewater reuse based on the United States Environmental Protection Agency guidelines.	100 per cent of wastewater. Sam Lord's Castle Hotel was formerly supplied with freshwater from a groundwater well, but because of the high water demand, especially for the irrigation of large expanses of lawns and garden plants, saline groundwater intruded into it to the point where the freshwater supply was virtually exhausted. The hotel received permission to use the treated effluent from its extended aeration sewage treatment plant for irrigating lawns and garden plants. Treated wastewater was diverted to irrigation use from its former disposal site in four deep suckwells.
Belize	The WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation reports that 90 per cent of Belizeans have an improved sanitation facility. It is estimated that 16 per cent of Belize's population is connected to a sewage treatment plant. In urban areas – in Belmopan, Belize City and San Pedro – most households (47 per cent) have toilets that run to a septic tank in their yard and many households (30 per cent) are also connected to a sewer system. By contrast, in	The 1996 Effluent Limitation Regulations include an effluent licence system which requires monthly reporting on effluent quality. The effluent limitation regulations were recently amended based on the LBS Protocol to address domestic sewage. The Government recently instituted a policy that	Wastewater reuse is mainly for irrigation purposes. An innovative alternative system is presently being used in Hunting Caye, the largest of the six cayes of the Sapodilla Cayes located in the south and has approximate area of six hectares. This system is also recommended for other islands especially those with high tourism potential.

[13] https://www.barbadostoday.bb/2016/10/30/bwa-clarifies-water-importation-from-suriname/

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
	rural areas, about 70 per cent of households use some type of latrine, 22 per cent have septic systems and 6 per cent have no toilet facilities at all. Many of the existing septic systems are not functioning properly, mostly because the designs are not to standard and only partially treat the raw sewage and grey water.	requires coastal and island developments to use package treatment plants for sewage treatment. Belize has no wastewater reuse guidelines	The Alternating Intermittent Recirculating Reactor (AIRR) system is an innovative alternative for the conventional drain field. It is designed to treat effluent in areas where percolation is limited or non-existent so the land can still be used for homes or business. This system employs the use of different types of bacteria to remove pathogens and to clean effluent water, which is then reused in above ground irrigation discharge into waterways or to drain underground.
Costa Rica	Approximately 98 per cent of the urban and rural population has access to a source of improved sanitation. However, there are serious disparities in some provinces and districts of Costa Rica with regard to access to sanitation. The national census in 2011 indicates that 20.5 per cent of the population has access to sewerage systems; 75.1 per cent use septic tanks; 0.9 per cent dispose of sewage directly to irrigation ditches, other ditches, rivers or estuaries; 3.0 per cent black pit latrines and 0.5 per cent use open defecation. According to estimations from the Instituto	The Regulation for Disposal and Reuse of Wastewater establishes the types of allowable uses for treated wastewater as well as the maximum permissible limits of a group of indicators according to the type of reuse.	Given the high availability of water, wastewater reuse is not given a priority. However, in the Central Valley, where 55 per cent of the population lives, untreated wastewater is used to irrigate a variety of crops.

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
	Costarricense de Acueductos y Alcantarillados (AyA) and PAHO, only 34.1 per cent of treatment systems in urban areas are operational. Nine per cent of urban sewage is treated before discharge and of that part, 46 per cent receives only primary treatment, with the remainder receiving secondary treatment.		
Guatemala	According to the WHO/ UNICEF Joint Monitoring Programme for Water Supply and Sanitation, access to sanitation services has slowly risen over the years in Guatemala. In 2004, 86 per cent of the total population had access to adequate sanitation, compared with 58 per cent in 1990. In urban areas 76.7 per cent of households have access to sanitation services, while in rural areas, only 16.8 per cent have access. Wastewater is treated in very few places (only 5 per cent nationally), so that the sewage flows into rivers and surface water, polluting other water resources.	Governmental agreement No. 236 - 2006 “Regulation for Discharge and Reuse of Wastewater and Sludge Disposal” establishes the criteria and requirements that must be fulfilled for the discharge and reuse of wastewater, as well as for sludge disposal. Legislation forbids the use of effluent to irrigate crops consumed raw.	Use of untreated wastewater is used in isolated cases for pasture.
Guyana	Approximately 84 per cent of households in Guyana used improved sanitation facilities. Approximately 5 per cent of the population – all within the capital city, Georgetown – has access to a sewerage system. The central sewerage system was constructed between 1924 and 1929 and the sewage is primarily discharged into the Demerara River untreated.	The Environmental Protection (Water Quality) Regulations, 2000 aim to protect Guyana’s waters by management and monitoring of effluent discharged into coastal and inland waterways.	While the Environmental Protection Agency encourages customers to do simple things like reusing washing water to water plants, wastewater reuse in Guyana is limited. The Guyana Wastewater Revolving Fund (GWRF) first generation project of Ashmins Fun Park and Resorts (an

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
	Outside Georgetown, the most popular method of treatment of sewage is through the use of individual septic tank systems which are frequently not constructed at the recommended distance from the water supply and overflow directly into the public drainage system and inevitably into creeks, rivers, and the Atlantic Ocean. The 2002 census noted that approximately 36 per cent of the population used this kind of system. A further 56 per cent had access to a pit latrine; and 2 per cent had no access to sanitation facilities.		eco-tourism and housing project) is planning to use treated wastewater from the new treatment plant for irrigation purposes in vital operations at the site[14].
Honduras	The WHO Joint Monitoring Programme indicates that approximately 69 per cent of the total population had access to improved sanitation facilities – 87 per cent of the urban population and 54 per cent in rural areas. Access to sewerage systems are 66 and 11 per cent in urban and rural areas, respectively.	There is no comprehensive legislation for wastewater management.	
Jamaica	In 2011, approximately 71 per cent of households had access to water closets; pit latrines were being used by 23 per cent of households; and approximately 2.1 per cent of all households reported no toilet facilities. In the Kingston Metropolitan Area, 92 per cent of households have flush toilets, while in other towns	The 2013 Natural Resources Conservation (Wastewater and Sludge) Regulations provide the regime for regulating the construction, modification and operation of wastewater treatment facilities and the discharge of sewage and trade	There are several wastewater reuse initiatives in Jamaica. Some hotels have used wastewater treatment effluent for golf course irrigation, while the major industrial water users, the bauxite/alumina companies, engage in extensive recycling of their process waters.

[14] http://www.stabroeknews.com/2015/news/stories/09/05/ashmins-communities-ministry-ink-pact-for-us300000-wastewater-treatment-plant/

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
	60 per cent of households have this facility. However, 42 per cent of households with flush toilets are not linked to wastewater treatment facilities (sewers), indicating that soil absorption systems are the predominant means of sewage disposal for the country. The quality of effluent treatment in Jamaica is mostly poor – a study of the performance of the Jamaican domestic wastewater sector conducted from 2001 to 2003, showed that only 40 per cent of the 60 plants monitored met the national effluent standards.	effluent. The regulations include standards for reuse for irrigation and agriculture – and provides for a reduced fee for effluent discharges if they are going to be reused.	Digesting and drying sludge from wastewater treated on-site and using on the grounds as fertilizer is practiced by the Sandals Group. The Jamaica Public Service Company – the country's electricity utility – is using treatment plant effluent for cooling and other purposes in the electricity generation process.
Panama	The WHO Joint Monitoring Program/2006 estimates access to improved sanitation was 89 per cent in urban areas (27 per cent for septic tanks and sewers) and 54 per cent (0 per cent for septic tanks and sewers) in rural areas. Within urban areas, access to sewers and septic tanks is significantly lower among the poorer residents.	Panama has regulations for effluent discharges directly into bodies of surface water and groundwater and also for discharges directly to water collection systems. Resolution No. 49 of February 2, 2000 approves the Technical Regulation DGNTICOPANIT No.24-99 on "Reuse of treated wastewater". This regulation establishes the requirements for water quality for different purposes (e.g. consumption by animals, irrigation, industrial, mining, recreation) after being	

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
		treated.	
Saint Lucia	Approximately 13 per cent of the population is connected to a treatment plant. Most homes and businesses have septic tanks. Castries is served only with a wastewater collection system which discharges raw sewage into the marine environment via a near shore outfall. The only wastewater treatment is applied to wastewater from Gros Islet, for which the Water and Sewerage Company employed an Advanced Integrated Pond System. Package plants, largely extended-aeration package plants used by hotels, generally operate well.	The Public Health (Sewage and Disposal of Sewage and Liquid Industrial Waste Works) Regulations (1978) state that no sewer fluid or liquid industrial waste may be discharged into any watercourse, river, stream, or any other place without the Public Health Board's permission. However there are no national standards. The National Water Policy includes the intention to investigate the feasibility of wastewater reuse	
St. Vincent and the Grenadines	Sewage treatment consists of septic tanks for collection and treatment and soak-away systems for disposal of effluent for both domestic households and commercial premises such as hotels, etc. Areas of central Kingstown are sewered, as well as a small area in Arnos Vale, not too far from the capital. Collected sewage is disposed via marine disposal.	St. Vincent and the Grenadines does not possess comprehensive wastewater legislation.	Wastewater reuse in St. Vincent is limited to household reuse for backyard gardening but in the Grenadines, it has been reported that 39 per cent of the resorts use treated wastewater.
Suriname	Wastewater from the city of Paramaribo drains indirectly to the river through the Saramacca canal. Greater Paramaribo is served by 25 sluices and/ or pumping stations. Part of the domestic	There is no specific legislation that regulates the overall water supply and sanitation sector. There are no laws for preventing	

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
	sewage (faeces and urine) is treated in septic tanks. The effluent of the septic tanks is collected in the street sewer. According to Bureau of Public Health and PAHO, 86 per cent of the houses have a septic tank. The remaining 14 per cent have pit latrines. The remaining portion of the domestic sewage, sullage, resulting from personal washing, laundry and from the kitchen enters the street sewer untreated. Septic tanks and pit latrines are emptied periodically at the home owner's expense by privately owned suction tank trucks. These trucks discharge their contents into the Suriname River. The problems inherent to Paramaribo are representative of those found in the rest of the coastal area. In the rural areas, pit latrines are used mostly and only a few houses are equipped with septic tanks.	the discharge of wastewater (industrial or otherwise) into surface waters, including rivers.	
Trinidad and Tobago	According to the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 92 per cent of persons in Trinidad and Tobago had an improved sanitation facility in 2015 – increased from 90 per cent in 1990. Improved sanitation facilities include flush/pour flush (to piped sewer system, septic tank, pit latrine), ventilated improved pit (VIP) latrine, pit latrine with slab, and composting toilet.	The Water Pollution Rules 2001 (as amended) aim to ensure that industries control and reduce the volumes and concentrations of pollutants discharged in their wastewater. The Water and Sewage Authority (WASA) has a Water Reuse Plan, in which wastewater will be	The Beetham Wastewater Treatment facility focuses on water reclamation for intended water reuse by other demand sectors. The plant employs some of the leading technologies such as reverse osmosis followed by ultra violet disinfection which has been proven to be an effective and an environmentally friendly treatment having higher virus

Country	Wastewater Management	Wastewater and sludge reuse	
		Legislative, regulatory and policy framework	Examples of reuse
	Twenty per cent of the population (mainly in the urban centres of Port of Spain, San Fernando, Arima and Scarborough) is served by central sewage treatment plants operated by WASA with 10 per cent being served by small privately owned plants, 64 per cent by on-site septic systems and 6 per cent by pit latrines. The Population and Housing Census 2000 indicates that in Port-of-Spain, 73.9 per cent of the population uses a water closet linked to sewerage system whereas in rural areas this figure is as low as 1.1 per cent; in Tobago on average it is 4.3 per cent.	treated and redistributed for industrial usage and will be made available to the country's fire-fighting network.	inaction, with no toxic by-products, in meeting the effluent quality standards set by the Environmental Management Agency.

Sources: Jimenez 2008, WASA 2007, WASA 2015, CReW 2014b, NEPA 2015, Silva 2013a, Silva 2013b, Silva 2013c, CARICOM 2009, UNEP 2014, CReW 2010, GOG 2009, Franklin and Daniels 2015, Wright 2014, UNHRC 2009, GEF CReW website (country profiles), GWP 2014, UNEP 1997, Peters 2015, (CHTA 2001).

In general, the level of wastewater reuse is influenced by freshwater availability, which is reflected in prices as well as the sources of domestic water supply to hotels and resorts and the agriculture sector and the size of the tourism and agriculture sectors. Where there is a high dependence on desalination and/or rainwater harvesting there is a tendency for greater use of wastewater. Hotel operators in the Eastern Caribbean have indicated that the price of potable water is a determining factor in the decision making on wastewater reuse (Peters 2015).

As Table 3 shows, some countries allow reused water to be used on crops that will not be consumed raw. In the United States, the use of reclaimed water for irrigation of food crops is prohibited in some states, while others allow it only if the crop is to be processed and not eaten raw. Some states may hold, for example, that if a food crop is irrigated in such a way that there is no contact between the edible portion and the reclaimed water, a disinfected, secondary-treated effluent is acceptable. For crops that are eaten raw and not commercially processed, wastewater reuse is more restricted and less economically attractive. Less stringent requirements are set for irrigation of non-food crops (BGR 2011).

Challenges to Reuse of Sanitation Waste in the Wider Caribbean Region

There are a number of technical, economic, social, regulatory and institutional challenges to the reuse of sanitation waste products – wastewater and sludge/biosolids. As noted, earlier in this report, concerns regarding the quality of the treated water and sludge to be reused and the long-term environmental, agronomic and health impacts must be addressed.

Peters (2015) asserts that in the Eastern Caribbean, the basic principles on which wastewater reuse is founded – providing reliable and adequate treatment of wastewater to meet strict effluent quality requirements, protecting public health and gaining public acceptance are influenced by cultural and social constraints, the state of the economy, technology and the availability of alternative sources of water. The key challenges to wastewater reuse in WCR countries include resource sustainability, public policy and regulations, as well as economic and technological considerations.

Availability of sanitation waste for reuse

Before wastewater can be reused, it must be collected and treated. However, in developing and low-income countries such as the WCR, only 8 per cent of the wastewater generated is treated (Peters 2015). As noted above, data from the JMP 2008 report indicate that only 39 per cent of households in Latin American and the Caribbean are connected to sewerage systems, which provide the opportunity to collect, treat and reuse sanitation waste products.

The tourism sector provides better opportunities to collect wastewater since many of them operate their own package plants – and indeed many hotels already practice wastewater reuse. In many countries, the tourism sector is the largest reuser of wastewater. This is a positive development since hotels are significant consumers of water – as well as producers of wastewater. Wastewater reuse can thus be a key part of self-sustaining water systems in the tourism industry. This will be important as the tourism industry expands within WCR countries.

Demand for treated wastewater may vary during different periods in the year. For example, during the rainy season and other wet periods, reuse of wastewater may not be needed for irrigation purposes (by hotels, golf courses, public parks, businesses and homeowners) and the challenge becomes how to dispose of this water during such periods.

Contaminants of emerging concern

A new concern that is coming to the fore as wastewater reuse is being promoted are certain chemicals that previously had not been detected but 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 (Peters 2015).

Regional guidelines and criteria for reuse of treated wastewater and biosolids/sewage sludge

One of the most critical steps in any reuse programme is to protect the public health, especially that of workers and consumers. To this end, it is most important to neutralize or eliminate any infectious agents or pathogenic organisms that may be present in the wastewater. For some reuse applications, such as irrigation of non-food crop plants, secondary treatment may be acceptable. For other applications, further disinfection, by such methods as chlorination or ozonation, may be necessary.

Therefore the regulation of reusing sanitation waste products is necessary. Table 3 above lists legislation and regulations related to sanitation waste that exist in CReW participating countries. Of the 13 countries, only four have specific legislation or regulations for reuse of sanitation waste:

- Costa Rica – Regulation for Disposal and Reuse of Wastewater
- Guatemala – Regulation for Discharge and Reuse of Wastewater and Sludge Disposal
- Jamaica – Natural Resources Conservation (Wastewater and Sludge) Regulations
- Panama – Technical Regulation DGNTICOPANIT No.24-99 on "Reuse of treated wastewater"

However, other efforts are underway. Trinidad and Tobago's Water and Sewage Authority (WASA) has a Water Reuse Plan. In 2013, Barbados began developing standards for wastewater reuse based on the United States Environmental Protection Agency guidelines, but adapted to meet the island's specific needs (Peters 2015). The legislative policy is intended to provide an enabling environment and controls so that 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. It requires that implementation of domestic wastewater reuse projects consider all relevant factors and risks including public health, environmental, economic, scientific, energy and public perception. Ultimately, in no event may water reuse be implemented if it poses a threat to public health (Peters 2015).

Jamaica's wastewater and sludge regulations specify standards for reusing sewage effluent for irrigation and for application to agricultural land as shown in Tables 4 and 5. Table 4 shows also the limits for discharge into Class I (the most environmentally sensitive) waters under the LBS Protocol. Table 4 shows that the standards for irrigation use are of course stricter than the LBS Protocol discharge standards. Table 5 is taken exactly from the sludge regulations document; currently there are no annual or cumulative data figures available.

Table 4: Standards for Sewage Effluent to be used for Irrigation

Parameter	**Standard Limit for Irrigation**	**Limit for Class I Waters**
Oil and grease	10 mg/L	15 mg/L
Total suspended solids (TSS)	1.5 mg/L	30 mg/L
Residual chlorine	0.5 mg/L	
Biochemical oxygen demand (BOD_5)	15 mg/L	30 mg/L
Chemical oxygen demand (COD)	< 100 mg/L	
Faecal coliform	12 MPN/100 ml	200 MPN/100 ml

Table 5: National Treated Sewage Sludge Standards for Fully Treated Sewage Sludge that can be Applied to Agricultural Land

Pollutant	**Maximum concentration # mg/kg (dry weight basis)**	**Annual pollutant loading rate**	**Jamaican Cumulative loading rate percentage kg/ha**
Arsenic	65		
Cadmium	75		
Copper	230		
Lead	90		
Mercury	0.045		
Molybdenum	09		
Nickel	180		
Selenium	14		
Zinc	400		
Chromium	830		165
Pathogens	<1,000 MPN/g of total solids (oven dried mass where viable helminth ova < 1 per 4g of total solids (dry weight) Salmonella < 3 MPN/4g Faecal coliform < 1,000 MPN/g		

The Regional Wastewater Management Policy Template and Toolkit prepared under the GEF CReW project, suggests the US EPA's guidelines for wastewater reuse (Table 6). This toolkit was developed to provide guidance in policy development and is intended as a practical reference guide for WCR wastewater managers develop and revise wastewater-related policies on behalf of their governments. The toolkit provides a range of fact sheets, case studies, ordinances, and other information that illustrate best practice.

Table 6: Guidelines for Water Reuse

Type of Reuse	Treatment Required	Reclaimed Water Quality	Recommended Monitoring	Setback Distances
AGRICULTURAL	Secondary Disinfection	pH = 6-9	pH weekly	300 ft. from potable water supply wells
Food crops commercially processed		BOD □ 30 mg/l	BOD weekly	
		SS = 30 mg/l	SS daily	
Orchards and Vinerds		FC □ 200/100 ml	FC daily	100 ft. from areas accessible to public
		Cl_2 residual = 1 mg/l min.	Cl_2 residual continuous	
PASTURAGE	Secondary Disinfection	pH = 6-9	pH weekly	300 ft. from potable water supply wells
Pasture for milking animals		BOD □ 30 mg/l	BOD weekly	
		SS □ 30 mg/l	SS daily	
Pasture for livestock		FC □ 200/100 ml	FC daily	100 ft. from areas accessible to public
		Cl_2 residual = 1 mg/l min.	Cl_2 residual continuous	
FORESTATION	Secondary Disinfection	pH = 6-9	pH weekly	300 ft. from potable water supply wells
		BOD □ 30 mg/l	BOD weekly	
		SS □ 30 mg/l	SS daily	
		FC □ 200/100 ml	FC daily	100 ft. from areas accessible to the public
		Cl_2 residual = 1 mg/l min.	Cl_2 residual continuous	
AGRICULTURAL	Secondary Filtration Disinfection	pH = 6-9	pH weekly	50 ft. from potable water supply wells
Food crops not commercially processed		BOD □ 30 mg/l	BOD weekly	
		Turbidity □ 1 NTU	Turbidity daily	
		FC = 0/100 ml	FC daily	
		Cl_2 residual = 1 mg/l min.	Cl_2 residual continuous	
GROUNDWATER RECHARGE	Site-specific and use-dependent	Site-specific and use-dependent	Depends on treatment and use	Site-specific

Source: USEPA, Process Design Manual: Guidelines for Water Reuse, Cincinnati, Ohio, 1992, (Report No. EPA-625/R-92-004)

Costs of Water Reuse Projects

Generally, water reuse is more expensive than drawing water from a natural freshwater source, but less expensive than seawater desalination. In many cases, lower-cost water sources are already being used, so the cost of water reuse should be compared with the cost of any available new water sources. The costs of water reuse vary greatly from place to place depending on location, water quality requirements, treatment methods, distribution system needs, energy costs, interest rates, subsidies, and many other factors.

Potable reuse systems can be more or less expensive than non-potable reuse systems. Non-potable reuse may require less treatment, depending on the intended use of the reclaimed water, and can also reduce the peak demand on a potable system, which can be a huge factor on water use in arid locations. However, non-potable reuse also typically requires a separate piping system, which can be a significant expense depending on where and how far the non-potable water must be distributed.

Water managers should consider also non-monetary costs and benefits of reuse projects, such as increased water supply reliability in times of drought and reduction in greenhouse gas emissions and ecological impacts, to determine the most socially, environmentally and economically feasible water supply option for their community.

Use of recycled/reclaimed waste-water often requires separate piping systems.

Public Preferences and Acceptability

Perhaps the largest obstacle to overcome will be attitudinal resistance to the idea of reusing "wastewater" and "sewage waste". Sometimes people are opposed to reusing treated wastewater, even when reclaimed water is shown to be of high quality. In some cases, people may even prefer lower quality water from a source perceived as "natural" over higher-quality water coming from an advanced wastewater treatment facility.

However, there is some level of acceptance for certain purposes. In the study "Potential Consumers' Perception of Treated Wastewater Reuse in Trinidad", Peters and Goberdhan report that the idea of non-potable use of treated wastewater for such purposes as firefighting and watering of public lawns was generally acceptable to the public. However, there was more apprehension about direct uses, particularly those involving human contact (Fai Pun 2016).

A study conducted with students at Ohio State University in the USA (Vedachalam and Mancl 2010) supports these findings. Researchers found that "low contact" uses (industrial manufacturing, firefighting, washing cars in a commercial facility, and flushing toilets in public restrooms) and "medium contact" uses (watering golf courses, flushing toilets in own residence, and watering personal lawns) had high levels of support. "High contact" uses (growing foods crops on a farm, discharge into a river, and for use in domestic washing machines) had low levels of support. The results indicated that most students lack information about certain facts and practices regarding water usage or wastewater. The survey showed strong support from students towards a water management and wastewater reuse program, but also demonstrated a need to educate them on issues related to water quality and quantity.

Any wastewater reuse programme will have to include a public awareness component to address some of the knowledge gaps and to encourage consumers to start supporting reuse initiatives that use recycled water for purposes with which they would be most comfortable.

"Judge water by its quality – not by its history."

International Examples of Wastewater and Biosolids/Sewage Sludge Reuse

The Wider Caribbean Region has many examples of application of wastewater for agricultural irrigation. Examples of wastewater and biosolids reuse in other regions of the world may be instructive to the region.

Reusing water for irrigation

Small-scale examples from the WCR using recycled wastewater for irrigation have been presented in Table 3 earlier in this report. An example from India shows how wastewater reuse can have social and economic impacts. In April 2016, The Mumbai Cricket Association (MCA) announced a plan that helped solve the problem of Mumbai's Wankhede Stadium hosting the home games of the Mumbai Indians franchise without depleting the state's water resources at a time of severe drought[15]. The MCA agreed to purchase water from the sewage treatment plant at a local race course. Recycled water was used in 17 of the cricket matches obviating the need for fresh water brought by tankers. Using scarce water to prepare cricket grounds in times of drought was seen by many as criminal waste with the cricket bodies facing heavy criticism. Furthermore, the racing club was asked to provide recycled water for surrounding communities as well.

Reusing water for potable water

In many WCR countries, groundwater is the most important source of potable water, with increasing pressures placed on this resource due to increased demand by municipal and industrial/agricultural uses as well as by pollution and saltwater intrusion. An example of wastewater reuse in California, USA to replenish groundwater is described here.

In 2008, Orange County started operating its Groundwater Replenishment System, which injects treated wastewater into the water supply of nearly 600,000 residents. Instead of using the water for landscape irrigation, the county is turning it into drinking water.[16] The Orange County system, like most potable reuse projects today,

[15] http://www.firstpost.com/sports/bccis-plan-for-ipl-during-drought-use-recycled-sewage-water-shift-some-matches-out-of-maharashtra-2724508.html; http://www.thehindu.com/news/will-use-treated-sewage-water-for-ground-maintenance-bcci/article8466066.ece

[16] https://www.greenbiz.com/blog/2013/12/16/drain-drink-innovations-wastewater-reuse

practices “indirect” reuse, which means there's an environmental buffer — for example, a groundwater basin or a reservoir — between the wastewater process and the municipal water supply intake. In direct potable reuse, there's no environmental buffer; water is treated and sent directly back to the municipal water supply. It's something that more, primarily arid, places are starting to consider as a way to make the most of their increasingly scarce water resources.

Experts say reuse technologies have been proven, and treatment plants can get wastewater as clean as distilled water. The three-step process used in Orange County — microfiltration, reverse osmosis and a combination of ultraviolet treatment with hydrogen peroxide — is becoming the standard for potable reuse.

Biosolids and forestry

The US Pacific Northwest is demonstrating the value of biosolid application to the healthy growth of forests, assisting both the forestry industry and providing ecological benefits[17]. Application of biosolids to forestland is recognized as an effective fertilization and soil conditioning mechanism. Biosolids enhance tree growth and the productivity of the entire forest ecosystem, including wildlife habitat. Biosolids may also help improve water quality of lakes and streams by increasing vegetation and enhancing the physical characteristics of forest soils, reducing erosion.

The value of biosolids is in their ability to amend the soil, both by providing nutrients (especially nitrogen and phosphorus) and by improving soil characteristics. The fine particles and organic matter found in biosolids can quickly enhance soil moisture and nutrient-holding characteristics. In the long-term, biosolids provide a continual slow release of nutrients to the soil as the organic matter decomposes and site productivity may be permanently improved. Most tree species grow faster when applied with biosolids; however, some respond dramatically while others show only a slight response.

Within six months of a biosolids application to a forest, understory plants are usually growing much more vigorously and displaying a deeper green color than before the application. This is not only visually pleasing, but can be of commercial value to people who harvest ferns and other vegetation for floral arrangements. Increased understory vegetation due to biosolids fertilization is also typically higher in nutrients and can provide better food and cover for wildlife.

[17] http://www.nwbiosolids.org/facts_forestry.htm

Restoration of aquatic ecosystems

In Costa Brava, Spain treated wastewater reuse projects were implemented to recreate wetlands. Reclaimed water was used to recreate wetlands and restore vanishing wet meadows, an ecosystem of high value and that has suffered a steady decline in the area since the 1960s. Damaged (polluted) ecosystems may benefit from the recycling of high-quality effluents that can be used to cope with environmental water demands instead of being discharged. Their reclamation with natural technologies produces an improvement in quality based on the development of trophic webs built upon nutrients still dissolved in the reclaimed water.

The main project in the Costa Brava area is that of the Empuriabrava constructed wetland system, where nitrified effluent is further treated to reduce the concentration of nutrients in the water and is reused for environmental enhancement. The new wetland will increase biodiversity in the area. This facility is also an interesting site for bird-watching – thus contributing to local recreation and possible tourism benefits (MED WWR WG 2007).

Turning sewage sludge into concrete

Researchers in Malaysia have discovered that dried sewage sludge can be recycled by adding it to cement to make concrete.[18] The researchers first produced domestic waste sludge powder (DWSP) by drying and burning wet sludge cake to remove moisture, and then grinding and sieving the dried sludge cake to make DWSP. Using varying proportions of DWSP (3, 5, 7, 10 and 15 per cent), the researchers mixed the material with cement to produce normal strength and two higher strength grades of concrete. They then compared each DWSP concrete mixture with normal concrete in terms of their compressive strength, water absorption, water permeability and permeability to salt.

Overall, the researchers found that while DWSP has a potential role in the manufacture of concrete, the performance – in terms of compressive strength, water absorption and water permaility – of DWSP concrete blends tends to decline with increasing concentrations of DWSP. However, resistance to salt increased for concretes containing up to 15 per cent DWSP. They have affirmed that there is potential for using DWSP as a partial cement replacement but that additional research is needed to improve the quality of the DWSP and the resulting cement.

[18] https://www.sciencedaily.com/releases/2016/06/160624140559.htm

Not only would this initiative result in a beneficial way to reuse biosolids, but it would also reduce the volume of naturally occurring minerals required for cement processing, with potential environmental benefits.

Generating energy from wastewater

A 2015 study by the World Resources Institute recently analyzed the potential for sludge-to-energy systems in Xiangyang, China. The study examined nutrient recovery, energy consumption, greenhouse gas emissions, reclaimed methane and cost of sludge disposal systems and found that sludge-to-energy systems can make a positive environmental impact.[19]

The city invested in a bioenergy plant that used a "high temperature thermal hydrolysis + highly concentrated anaerobic digestion + methane capture and utilization" pathway through which co-digested sludge and kitchen waste was treated to make it safe and to provide a renewable source of energy. The plant converted the organic matter (sludge) left over from treated sewage into electricity. The plant heats the solid waste, then employs microbes to digest it, which produce methane. The plant then burns that methane to generate power for water treatment. Excess methane can generate electricity for the facility, or power cars as a substitute for compressed natural gas (CNG). In addition, leftover solid waste is sterilized, and can be used as fertilizer for certain types of crops. Other sludge-energy byproducts – called biochar – can be used to grow potted trees on landfill sites to restore landscapes or on city streets to help lower temperatures and improve air quality.

Sludge-to-energy systems can reduce solid wastes, greenhouse gases and water pollution, and at the same time save money. Selling fertilizer, biochar and even extra energy back to the grid can create new revenue for a wastewater treatment plant. This project successfully achieved the goals of financial viability of the enterprise, sludge stabilization through pollutant reduction, resource recovery, close to zero net carbon emission from the wastewater system, and renewable energy generation in the city.

[19] http://www.wri.org/blog/2016/03/world-water-day-how-sludge-can-power-chinas-cities-while-cutting-emissions?utm_campaign=socialmedia&utm_source=facebook.com&utm_medium=wri-page

Conclusions and Recommendations for Wastewater and Biosolids/Sewage Sludge Reuse in the Wider Caribbean Region

The countries in the Wider Caribbean Region have a definite rationale for increasing the use of recycled/treated sanitation waste products. Two major economic sectors in the region – tourism and agriculture – are large consumers of water and depend on a supply of freshwater. In turn, they also produce large volumes of wastewater, thus providing a potential source of freshwater if wastewater reclamation efforts are institutionalized. Also, many countries in the region are considered water scarce, therefore putting a premium on finding alternate sources of freshwater. Additionally, countries in the region are committed to increasing their use of renewable energy. This focus on alternate energy provides an impetus for developing programmes that use biosolids to provide energy – to complement more established renewable energy technologies such as solar, wind and hydropower. Water and wastewater utilities, therefore, should look to establish linkages with the agriculture and energy sectors to improve efficiencies and to create value-added, competitive products and services.

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The main use of reused wastewater in the Wider Caribbean Region is for irrigation of agricultural land, small farms, gardens, hotel grounds and golf courses. However, this use is seldom governed by relevant regulations and standards, often because of the low priority placed on wastewater management in general and wastewater reuse in particular. One area of relative high wastewater reuse is the tourism industry, where individual hotels are in control of their own wastewater treatment and the incentive and opportunity for using recycled wastewater are high. A few hotels process and use sludge on property as fertilizer, but this should be done only if the sludge has been properly digested and stabilized and it is applied in areas not accessible to staff or guests. There is considerable opportunity for growth in the reuse of sanitation waste products.

Based on the characteristics of the Eastern Caribbean countries and after interviews with water professionals in these countries, a number of conditions were identified that can be used as indicators of good potential for wastewater reuse. These conditions are relevant in countries of the WCR but can be adapted to the specific country characteristics. Table 7 provides a list of potential conditions. A positive answer to a pre-determined number of these conditions for a country would suggest that wastewater reuse can be positively considered. Similarly, Table 8 presents conditions that suggest the potential for reuse of biosolids/sewage sludge.

Table 7. Examples for preliminary assessment of the potential of a country for wastewater reuse

	Condition	Answer
1.	Absence of surface water	Yes/No
2.	Absence of groundwater	Yes/No
3.	Annual rainfall less than 1,000 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$ 200/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.	Water use by the agriculture sector greater than 50% of total demand	Yes/No
12.	Adequate legislation in place	Yes/No

Table 8. Examples for preliminary assessment of the potential of a country for biosolids/sludge reuse

	Condition	Answer
1.	High dependence on imported oil	Yes/No
2.	Renewable energy programmes being pursued	Yes/No
3.	Wastewater collection system in place	Yes/No
4.	Collection of biosolids in place	Yes/No
5.	Presence of agriculture industry	Yes/No
6.	Adequate legislation in place	Yes/No

Reuse of sanitation waste products to enhance the region's water, food and energy security fits into regional and national initiatives to promote sustainable development and the Green Economy within the context of adapting to the global challenge of climate change. Countries in the region are being supported in their movement towards the Green Economy through international initiatives such as the UNEP Green Economy Initiative and European Commission-supported regional project Advancing Caribbean States' Sustainable Development through Green Economy.

A circular economy:
An economy "based on closed-loop systems and cradle-to-cradle and industrial ecology concepts, an industrial economy that is restorative, relies on renewable energy and eradicates waste by considering waste from one process as a resource for another process"

- Ellen McArthur Foundation

The Green Economy promotes the idea of the "circular economy." The very concept of using waste products from one system as inputs into other systems is an integral part of the circular economy.

Recommendations for increasing the use of sanitation waste products in the Wider Caribbean are described below.

Develop appropriate policies regulations, standards, and guidelines for sanitation waste reuse

The critical step in promoting increased, safe reuse of sanitation waste products is always the development of an enabling legislative and regulatory environment. As shown in this report, some countries have made excellent progress in this regard – notably Costa Rica, Guatemala, Jamaica and Panama. As more regulations are developed and approved, it will be critical to implement adequate enforcement and monitoring systems.

In November 2015 the International Standards Organization (ISO) announced it had published new standards on treating and reusing wastewater for agricultural irrigation projects.[20] The ISO 16075 series contains guidelines for the development and execution of treated wastewater projects, including design, materials, construction and performance. It covers issues such as water quality, types of crops that can be irrigated, associated risks and main components (e.g. pipeline networks and reservoirs).

The ISO believes that this new standard for treated wastewater can help key players in irrigation maximize the benefits and reduce any related risks for their agricultural irrigation systems. The ISO 16075 series includes:

- ISO 16075-1:2015, Guidelines for treated wastewater use for irrigation projects — Part 1: The basis of a reuse project for irrigation. This contains guidelines for all elements of a project using treated wastewater for irrigation.
- ISO 16075-2:2015, Guidelines for treated wastewater use for irrigation projects — Part 2: Development of the project, which covers issues such as criteria for the design and specifications for quality.
- ISO 16075-3: 2015, Guidelines for treated wastewater use for irrigation projects — Part 3: Components of a reuse project for irrigation.

Each country in the region should examine its national standards in relation to international guidelines to ensure that it is up-to-date and uses the most recent data.

Change focus of water/wastewater utilities

A change in attitude towards wastewater could lead to wastewater treatment plants being seen as “water resource recovery facilities[21]”. These utilities would thus become institutions central to the implementation of the circular economy. The International Water Association (IWA) has recently published a framework for water utilities: *IWA: Water Utility Pathways in a Circular*

[20] http://www.watertechonline.com/iso-releases-new-standards-on-use-of-treated-wastewater-in-agriculture/
[21] https://www.newsdeeply.com/water/community/2016/08/02/making-the-most-of-wastewater

Economy that describes transitionary pathways for utilities that position them as engines for sustainable growth. Instead of wastewater treatment plants, countries should begin to design them as "resource factories", "energy generators" and "used water refineries" (IWA 2016).

The framework presents three interrelated pathways – for water, materials and energy – that aim to help utilities identify integration points within systems that enable their transition to the circular economy. It identifies practices, approaches and business models for utilities that can lead to greater efficiency of water use, lower fossil fuel consumption and providing valuable materials for manufacturing and agriculture. Examples from the framework include energy production at the water distribution network, and recovery of fertilizers from wastewater (IWA 2016).

Key elements of the water, materials and energy pathways are listed below.

Water	Materials	Energy
• Investments in conservation and pollution control • Rainwater harvesting • Greywater recycling for non-potable reuse • Greywater for agriculture and aquaculture • Reused (treated) water for agriculture and aquaculture • Reused water for tourism and other industries • Direct potable reuse • Reduction in leakage / water loss • Reduction in water consumption	• Improving resource efficiency • Used water sludge and products for agriculture • Organic waste added to used water sludge to increase biogas production • Drinking water sludge to agriculture or industry (an opportunity even though less in volume than wastewater slidge) • Bioplastics from wastewater • Fertiliser (non-agricultural - e.g. parks, golf courses) • Building materials from sludge • Effluent gas reuse (e.g. methane)	• Energy saving at treatment plants and distribution systems • Energy reduction and recovery at home • Heat produced from distribution systems • Biosolids to energy production (gas, electricity and heat) • Renewable energy

Explore recycling treated wastewater for 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 (Peters 2015). This technology is suited to the more arid islands in the Caribbean, such as Antigua and Barbuda or to countries that have large-scale wastewater treatment plants such as Trinidad, where the Beetham wastewater treatment plant now discharges over 50 million litres of treated wastewater per day or Jamaica with the Soapberry Treatment Plant.

Promote reuse of greywater

Many informal water conservation initiatives implemented by water utilities and national environmental agencies (for Guyana's Environmental Protection Agency) encourage citizens to reuse water from their kitchens etc. However, most household wastewater is discharged directly into drains. Many 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. Decentralized wastewater reuse technologies can have applications in housing developments, conventional hotel complexes and resorts, including resorts in remote locations. Programmes to promote reuse of greywater should include appropriate education and technological support.

Focus on the tourism sector

Treated wastewater reuse should be promoted in the hotel and resorts industry or subsector – building on the existing successes in this sector. Treated wastewater reuse allows the hotel and resorts sector to reduce the overall costs of water supply, overcome shortages in the dry season and meet stringent wastewater disposal requirements. Treated wastewater reuse can meet a large percentage of the needs of major hotels and resorts if it is employed for irrigation and toilet flushing. The potential and the opportunities for treated 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 used as required within the cluster. The hotel industry should focus on treated wastewater reuse as a way to guard against higher costs or diminished water supply. Organizations such as the Caribbean Alliance for Sustainable Tourism (CAST) have programmes to support hotels in efforts to implement environmentally friendly practices such as treated wastewater recycling and reuse.

Address public perceptions

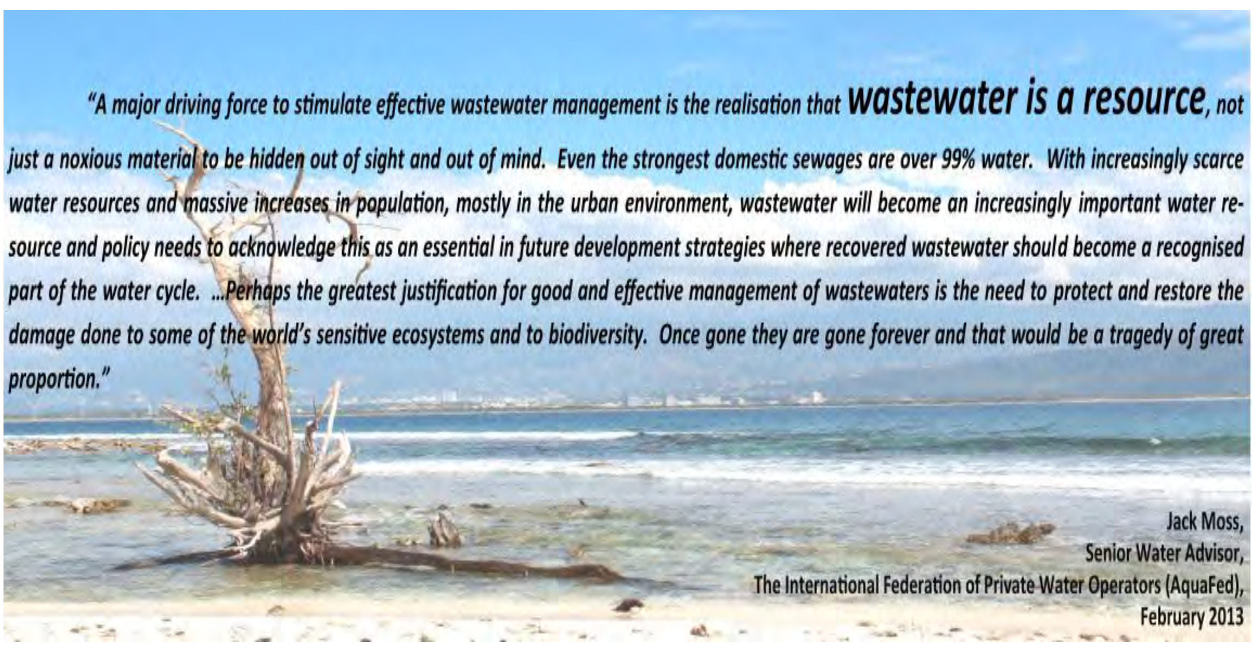
Reuse of sanitation waste products bears a certain social stigma in the Wider Caribbean Region. Any reuse initiatives must address the public's perception of wastewater treatment as being a "waste of money, gross, and not a workable option for helping to solve the region's water problems". [22]

[22] http://shaefferb.blogspot.com/2014/11/wastewater-reuse-in-caribbean.html

The success or failure of a proposed reuse project often depends on public perceptions of how the project relates to public health, taste and aesthetics, land use, environmental protection, and economic growth. Perception is usually influenced by the public's mistrust of the local water authorities to deliver safe and high quality water; a general lack of knowledge of treatment processes used; and perceived or prior negative experience with health risks associated with using treated wastewater (Fai Pun 2016, Vedachalam and Mancl 2010). However, there are uses for recycled or reclaimed wastewater that have general public approval – such as irrigating golf courses, firefighting and flushing toilets. Therefore, there are opportunities to gain initial support from potential end-users for sanitation waste reuse if end uses are chosen carefully.

Rightfully so, consumers are concerned about health safety. This concern could be transferred into support of sanctioned reuse of treated waste. Using wastewater for irrigation of farms and agricultural land is already common in the Wider Caribbean Region. Some of this wastewater is untreated or inadequately treated; by ensuring that wastewater is treated to acceptable – safe – standards, potential users should be more interested in participating in reuse projects. Demonstration projects, which educate the decision makers, managers and communities, provide opportunities to change the public's perceptions in this area.

When communities are actively engaged in discussions about wastewater reuse, the technologies and science behind it, and the overall context of water management, both the public and water managers are better equipped to engage in meaningful dialogue. Frequent and open communication among water managers, citizens and governments can be critical for communities to address the concerns of the public and make informed decisions about reuse of sanitation waste.



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