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Exploring Solid-Waste as an Indicator of Sustainable Development in Small Island Developing States (SIDS): A Case Study of Tortola, British Virgin Islands (BVI)

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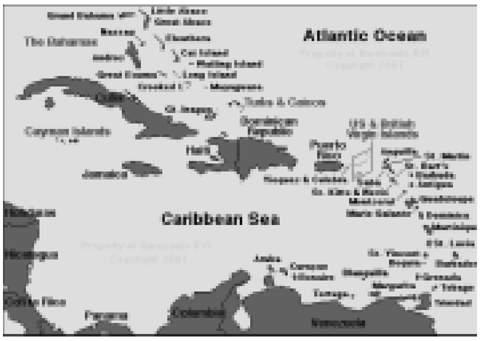
ABSTRACT

In 1999, despite having the only municipal incinerator in the insular Commonwealth Caribbean, substantial growth in solid-waste quantities threatened to precipitate a crisis in Tortola, BVI. Considering the implications for limits to growth reflected in this problem revealed that Caribbean small island states have been neglected by and are neglecting the question of physically assessing progress towards sustainability. This is unfortunate both for the islands themselves which are in critical need of some practical means to monitor their situation and because of the insights that examination of island problems may provide to the larger world context.

The entropic nature of economic processes determines that material flows are the physical basis for sustaining human economies. Understanding this, the utility of waste as a sustainability indicator in Tortola was explored. Analysis of socio-economic data, waste management system capacity, waste receipt data, and estimates of resident vs. tourist contribution to Tortola's waste stream evidenced two unsustainable trends. First, increasing waste ouput per unit of economic input. Second, the tourist population exceeding the island's carrying capacity as delimited by island's present capacity to store, collect, treat and dispose of wastes. Waste was therefore shown to be a viable indicator. It is recommended that Tortola develop material-flow accounts and provide an example for other Caribbean island countries.

1 Introduction



"This oval-shaped formation of the islands has turned out to be one of the best pleasure boating areas in the world. On land, the BVI is endowed with fine mountain ranges, small valleys and little flat fertile agriculture land. The geography of the BVI has been responsible for the natural assets used in the production of tourist services," (DPU 2002).

Figure 1: Map of West Indies

The only municipal solid waste incinerator operating in the insular Commonwealth Caribbean is located at Pockwood Pond on the small island of Tortola in the British Virgin Islands[1] (Lettsome 1998a; Solid Waste Department 1997a). At 54 square kilometres, Tortola is the largest and most populated of the British Virgin Islands (BVI), an archipelago of 35 - 40 islands, rocks, and cays, located in the Caribbean at the northern end of the Lesser Antilles chain some 60 miles east of Puerto Rico (BVI 1999). The islands, except for the coral atoll of Anegada, are volcanic in origin, with steep hilly terrain and very little flat land.

1.1 History and Development

The Virgin Islands group, in addition to the BVI includes the three larger islands and associated cays of the neighbouring United States Virgin Islands (USVI). Successive settlement attempts by various European factions eventually resulted in permanent British possession of the more numerous smaller islands from 1672 onwards, and Danish possession of the larger three islands that were sold to the United States in 1917 (Dookhan 1975).

The early colonial period (17^{th} - 18^{th} centuries) saw logging of the original tropical rainforest vegetation, clearing of land, importation of African slaves for labour and establishment of a plantation economy with sugar, rum, and later cotton being the main export products (Encontre 1989; Pickering 1987; Dookhan 1975). The territory's economy experienced several cycles of "boom and bust" as demand for these products increased and declined.

After the end of World War II the territory's economy re-entered a period of decline. (Pickering 1987; Dookhan 1975). At the time, the economy was based largely on remittances from employment abroad and subsistence agriculture. The main exports of livestock, fish, and produce were traded almost exclusively with the neighbouring USVI. Many BVIslanders worked in the USVI, but they also found employment in other Caribbean islands or migrated to the mainland US.

1.2 Tourism and Financial Services

From the 1950s onward the BVI turned its attention towards economic development and

[1] The BVI is one of the United Kingdom's few remaining Overseas Territories.

modernization. The "slow decline of agriculture" resulted from organized promotion of tourism which "was seen as a way of providing jobs, increasing the flow of money into the BVI and keeping the labour force from emigrating to St. Thomas, the USVI and the USA," Pickering (1987, 77).

During the 1970’s and 80s the BVI developed into a world renowned charter boat destination. The tourism industry grew at an average annual rate of 19% during the 1970s, declined in the early 1980s to an average annual growth rate of minus 6%, then began to grow again from 1985 onwards, at a rate of 5% (Encontre 1989). Growth fluctuated during the 1990s but the BVI experienced an average annual growth rate of 6% from 1991 to 2000 (DPU 2001). The number of overnight visitors to the BVI rose from about 50,000 in 1977 to well over 470,000 in 2000.

Attempts to diversify the economy led to development of the financial services industry during the 1980s. The BVI's financial services products include registration, regulation, and management of international business companies (IBCs), trust companies, captive insurance companies, and mutual funds (BVI Financial Services Review 2002; Business Age 1995). In 1991, financial services accounted for 11% of the GDP. This increased substantially to 30% in 1994 and grew to 38% by 2000 (DPU 2001). In the mid-1990s, financial services displaced tourism as the leading revenue earner, accounting for some 50.2% of the public purse in 1999 (BVI 2000).

1.3 The 21st Century …

The twenty-first century meets the BVI with an economy that has grown phenomenally during the previous five decades and now rests on two pillars, tourism and financial services (Georges 2001). The population, fuelled by immigration of skilled labour, has doubled since 1980 to over 20,000 people. Land-based visitor accommodation grew from 300 beds in 1969 to 1,235 beds in 2000 (DPU 2001; Encontre 1989). It had the highest tourist per capita ratio of all island economies with populations less than one million in 1987; and the highest tourist per capita ratio among Caribbean small island states from 1993 - 1997 (UNEP 1999). The per capita GDP increased from $64.50 ($US) in 1947 to $32,927 in 1999. Overall, the growth of the BVI's economy has simply been spectacular (Smith 1997).

However, economic development since the 1950s has visibly affected coastal, marine and terrestrial ecosystems in the BVI. Dick-Read and Blok (2000) comment that:

> *Many of us are already forgetting what it was like before Wickhams Cay was developed and mangrove islands existed in Road Harbour; when Cane Garden Bay was a sleepy village; when Pockwood Pond was a dark, mystical mangrove forest; and Sopers Hole was teeming with bonito. These are some of nature's little secrets that have been sacrificed in the quest for development. . . . this generation has seen 75% of Tortola's mangrove forests and sea grass beds destroyed in one generation.*

Near-shore water quality in some areas has declined due to sewage, chronic coastal oil-pollution in areas with high marine traffic, and muddy run-off (BVI 1998). Dive-sites and coral reefs have suffered from high volume use and anchor damage over the years. Several wetlands (swampy coastal areas with mangroves and ponds) have fallen victim to the desire to create flat land for development (DPU 1994). Many of these were conveniently filled with garbage. The cumulative effect of several thousand sailors discharging raw sewage and toilet paper within BVI's near-shore waters has begun to take its toll (Osburne 2002). This type of despoliation is a typical feature in many island environments (UNEP 1999; Singh 1996; McEachern and Towle 1974a).

1.4 Limits to Growth in the BVI?

The particular focus herein is the explosion in solid-waste that has occurred as a result of the territory's growth and development. Despite the high cost[2] of the technology, and possible environmental and health effects of the emissions, Tortola had selected incineration as the means to be rid of "noxious smoke" while getting better volume reduction prior to disposal than that afforded by traditional open-burning (SWD 1997a). Commissioned in 1994, when average waste generation was around 20 tons/day the incinerator was hailed as an end to the solid waste problem. But by 1999 - 2000 continued growth in waste generation, coupled with lengthy unscheduled breakdowns and lack of a landfill site on Tortola, led to a mountainous back-log of unprocessed waste being stored on and around the incinerator grounds. By 2001, a mere seven years after having the most technologically intensive solid waste disposal system in the region, the island was once again faced with the very pressing question of what to do with its waste.

When this research project began, a proposal to develop a landfill site on a rocky mountainside in Tortola was under consideration (Macguire Group Inc. 2001a; 2001b). The excavation and operation of a landfill site on this steeply-sloped parcel of land would have been sure to cause an unsightly scar on the mountainside, and negatively affect marine water quality and biota immediately down slope.

Pursuing such a course of action seemed potentially inappropriate for a country whose economy was heavily dependent on "unspoilt" natural beauty and pristine, crystal-clear, waters. It also seemed that such a move had implications for the island's environmental sustainability. If the only waste disposal site that could be found was an unsuitable one, or none at all, did that not indicate some problem of a fundamental nature? Was the island's economic activity exceeding its environmental capacity? Was the solid-waste problem a manifestation of reaching limits to growth? Was this island community moving away from sustainability?

2 Assessing progress towards sustainability in sids

The issue of assessing progress towards sustainable development at a national level has been on the global agenda for just over a decade, since the adoption of Agenda 21. It is a developing field of both study and practice where we are still striving to identify indicators, methods and criteria to assess our progress towards a goal which remains somewhat undefined (European Communities [EC] 2001).

Small island developing states (SIDS) in the Caribbean, as parties to Agenda 21, also bear a responsibility to monitor their national progress towards sustainable development, but their voices seem to be absent from the discussion at the international level. Progress reports on the implementation of the Barbados Programme of Action for the sustainable development of SIDS address the actions/strategies/programmes put in place by national governments. They do not measure whether an island country is actually becoming more or less sustainable. This absence is unfortunate exactly for the point raised by Bass and

[2] For most Governments in the region, incineration is economically unfeasible. Dumping or unsanitary landfilling coupled with open-burning remains the predominant practice (UNEP 1999; Walker 1996; CCA/IRF 1991).

Dalal-Clayton (1995):

> *Little attention has been paid to the experiences of small islands and micro-states. Yet it is here where many of the issues which need to be faced in considering paths towards sustainable development are most sharply brought into focus. In small islands, economic, social and environmental changes are more likely to impact on the whole country than in large land-based countries.*

The characteristic small size of SIDS holds out the promise that research about national progress towards sustainable development in SIDS should be less complex than in continental areas. The applicability at all scales of lessons about human-environment interactions holds out the promise that SIDS research should be meaningful. These two possibilities stem from the characteristic smallness of island and society that are usually cited as a disadvantage. However, certain SIDS characteristics remain challenges. As it pertains to sustainable development research, a limited pool of locally available skills inhibits the ability of SIDS to carry out research and implement programmes (Hess 1990). Limited finances also remain a problem.

Agenda 21 has stimulated many national efforts to develop sets of sustainable development indicators (UN 2001). But Maureen and Hart (1998, 26) comment that "most developing nations lag behind in the implementation of sustainability indicators". Agenda 21 recognizes a general lack of capacity in developing countries to collect, process and disseminate information (UNCED 1992). Further, that the gap in the quantity and quality of information available in developing countries places them at a serious disadvantage in making informed decisions on environment and development.

Small island developing states remain peculiarly vulnerable to these information management challenges (UN 1994). For example, Villamil (1977) emphasizes that diseconomies of scale also exist in research and the cost of research needed to develop and plan appropriate development paths for SIDS is probably beyond the range of any individual country. One can easily imagine that undertaking extensive research across all areas of sustainability would be unfeasible for many island countries. SIDS, therefore, must choose, and should invest resources in monitoring those indicators which give the best picture of sustainability and the best policy relevant advice. International effort has been focused on the development of a vulnerability index for SIDS - a means to measure the lack of economic resilience because of factors beyond their control (Briguglio 1995). It appears that the majority SIDS have yet to tackle the issue of how to assess their progress towards physical sustainability.

3 Waste as an indicator of sustainability

Using waste as measure of progress towards sustainability logically arises from a fundamental understanding of the thermodynamic nature of the economic process and its irrefutable connection with the environment as a source for materials and a sink for wastes (Costanza *et al.* 1997; Georgescu-Roegen 1976a; 1976b).

Waste generation is an inevitable consequence of life processes. Within all living organisms, thousands of biochemical cellular reactions take place every second (Fischer-Kowalski 1997; Purves, Orians and Heller 1992).These reactions sustain the metabolic processes of cell maintenance, growth and reproduction. To survive, an organism must acquire raw materials to fuel metabolic reactions, and dispose of the resultant wastes.

The organism's environment provides for both these needs, serving as the source of food or raw materials and as a repository for wastes (Georgescu-Roegen 1976a).

As a culturally and technologically advanced species, human material needs entail more than just basic biological requirements for air, water, and food. They also include energy and materials to maintain our social organization or society. Energy and materials are needed to provide shelter and clothing, organize and support food growing and distribution systems, education, communication and transportation systems, military, spiritual and recreational activities (Georgescu-Roegen 1976b).

As a social species humans organize collectively in communities or societies, to acquire resources from their environment. Humans engage in various activities to obtain, process, use, and dispose of the materials required to maintain their societies, and ultimately themselves. These are termed 'economic' activities (Gowdy and O'Hara 1995). Economic activity in society is akin to metabolic activity in the body, in that sustaining economic processes also requires the acquisition of raw materials (e.g. ore) from the environment. Within the economy, materials are transformed (e.g. iron metal) and used (e.g. iron tools) to keep society functioning. Similarly, unwanted by-products or wastes occur at each stage (e.g. tailings, contaminated water, rusty tools) and are released back into the environment.

Georgescu-Roegen (1976a) proposed that survival of the human-species poses a bioeconomic problem. Our survival is not only dependent on maintaining the input of resources and the output of wastes to sustain biological metabolism. We are so dependent on our exosomatic 'limbs' (e.g. cars, tractors, tools), that survival also requires society maintain the input of resources to support economic activity. Since materials for economic uses are mobilized outside of the body, at a level higher than individual human, the term 'exosomatic' metabolism is used to refer to the economic processes of society as a whole (Ayres 1994).

Present human production and consumption patterns are unsustainable because of the ecological devastation involved in the way we exploit both living and non-living resources, and dispose of the wastes which arise from processing, consuming and discarding these materials (Wackernagel and Rees 1996; Gourlay 1992). In effect, we have developed "throughput" economies that employ materially inefficient and dissipative practices. We unnecessarily increase material entropy in the global system by maximizing the extraction of resources and the disposal of wastes into the environment (Daly and Cobb 1989).

Physically, sustainability necessitates acknowledging and respecting biophysical limits to economic activity (Costanza *et al.* 1997; Wackernagel and Rees 1996; Daly 1990; Ehrlich 1989). Given the current unsustainable scale of economic activity relative to the global ecosystem, sustainability requires reduced resource extraction, more efficient production processes, reduced consumption (especially reduced dissipative use of materials), and increased cycling of materials within the economic system. By minimizing material throughput, these actions would result in less environmental damage from resource exploitation, processing and consumption. They would also result in less waste for disposal and less pollution. Thus, the amount of economic wastes naturally reflects the success or failure of actions taken to move towards sustainability (EC 1999).

4 Case study of tortola – the waste management system

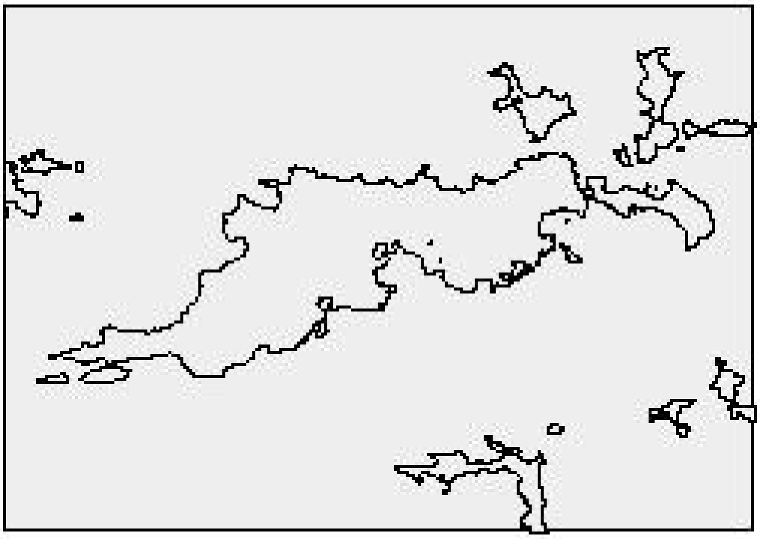


Figure 2: Map of Tortola

Responsibility for Solid Waste Management in Tortola lies with the Solid Waste Department (SWD) under the Ministry of Health and Welfare. Duties of the SWD include garbage collection, disposal, dumpsite management, island beautification, and waste education (Williams 1991). The SWD is headed by a Manager of Solid Waste who oversees a staff of some 80 persons (BVI 2000). Departmental functions are subdivided into administrative duties, education activities, incinerator plant management, and collection and disposal activities.

4.2 Storage and Collection

Waste generation data for Tortola actually represent the amount of garbage the collection system delivers to the incinerator. Instead of door-to-door collection, there is a public storage system of over 250 receptacles consisting of 200 litre (55 gallon) drums, wooden bins, concrete bins, and steel bins varying in capacity from 1.5 m^3 (2 yd^3) to 6 m^3 (8 yd^3) (SWD 2001; SWD 1996). These are located along main roadsides and in accessible locations within communities. Individuals must take their own garbage, usually contained in plastic garbage bags, to the bins which are emptied by schedule 4 - 7 days a week. The garbage is then transported to the Pockwood Pond incinerator facility.

Collection services for bins are provided by the SWD and two private contractors (SWD 1996, Walker 1996). They use compactor trucks which are able to empty the steel bins mechanically, but other receptacles must be emptied manually. Wastes are also transported to the incinerator compound in private vehicles and pickup trucks. Commercial generators (e.g. supermarkets, construction companies) are supposed to make private arrangements for storage and transport of wastes from their place of business to the incinerator (SWD 1997). Cruise ship agents arrange for private contractors to take their wastes to the incinerator. Bulky household goods and yard wastes should be taken to the incinerator by individual generators and some do so, but old appliances and mattresses are frequently left next to bins. The compactor trucks cannot accommodate these items so the SWD arrange for their collection.

4.3 Treatment

The BVI Government purchased and installed a Consumat CS 1600 two-stage, ram fed incinerator at a capital cost of $3.5 million. Operations began in 1994, and operating costs were $450,000 in 1996. The burn rate is specified at 40 tons per day. All solid wastes, except derelict vehicles, are received at the incinerator plant (SWD 1996). Once weighed, loads of non-combustible wastes and bulky items are sent directly to the landfill site. Presently the incinerator operates on a 24 hour schedule, 7 days a week.

When initially commissioned, 40 ton/day capacity was considered sufficient for Tortola's needs well into the future. Capacity limitation (45 ton/day) occurred in 1998, and was exceeded by 1999 (51 ton/day). A significant backlog began to accumulate at the compound, which grew to mountainous proportions when the incinerator had to be shut down for unscheduled repairs at the end of 1999 - beginning of 2000. Much of it was eventually burned openly. The untenable position of constantly receiving more waste than can be processed daily prompted the Department to lobby for another incinerator plant, a request which has been favourable received. An estimated 50 - 60% of incinerator ash is melted (slag) or broken glass which has not been removed from the waste stream.

4.4 Disposal

Reliable disposal capacity has always posed a problem for Tortola since most dumpsites have been located on private land (Walker 1996, Scheu 1993; Dillon 1988). In 1993 a solid waste disposal study was conducted by Scheu (1993) under the Caribbean Environmental Health Institute Environmental Health Improvement Project (Sweeny 1994). Scheu (1993) concluded that the need to protect steep mountainsides, and the water catchment areas of alluvial valleys left very limited options for disposal sites. There was already development along most of the coastline. He was unable to identify suitable possible sites on the north-west side of the island. On the north eastern side, potential sites at Josiah's Bay and Thomas Land were likely slated for tourism and residential development respectively. On the south side of the island three areas, Coxheath, Duff's Bottom, and Pockwood Pond, were identified. Given Coxheath's lack of residential development at the time, it was in his opinion, the most suitable location for a long term ash/refuse disposal site on Tortola.

Despite Scheu's recommendations Tortola lost its officially designated landfill site on July 1, 1996, when the lease at Coxheath was not renewed (SWD 1997). Lack of an alternative storage site was a major factor in accumulation of the mountainous backlog of waste. Presently, disposal of ash and non-combustible waste takes place at Pockwood Pond quarry adjacent to the incinerator compound, on a temporary site leased from a private company, Tortola Concrete Products (TCP), at approximately $50,000 per year.

5 Trends in solid waste 1995 - 2000

Recent data on MSW generation in Tortola is provided by SWD records and annual reports. This data is derived from waste collection receipts gathered at Pockwood Pond incinerator facility which is equipped with a truck scale. Accuracy of the data is limited by the following factors:

- **<u>Lack of public co-operation</u>** – Drivers do not always comply with weigh scale procedures.

- **Weigh scale maintenance** - The truck scale has capacity 50 tons (110,000 lbs or 50,000 kg) and an accuracy of +/- 10 lbs (5 kg). If the scale is not calibrated nor damaged parts replaced it can introduce positive or negative errors into readings. Malfunctions have occurred in the past, however, those occasions and which weight records were affected are not noted in records or annual reports.

- **Inconsistent record keeping** - The plant is open to receive wastes on a 24 hour basis but the scale room is sometimes unmanned during evening and night shifts.

Overall, recorded amounts are likely to be less than actual amounts of waste received. Also, growth in recorded waste amounts probably reflect in some measure increasing information capture by the Department, as well as increasing waste amounts.

Utility of the data is limited by the following factors:

- **Analytical value** - It has been assumed that the relative proportion of materials in Tortola's waste stream has remained more or less constant since the only attempt at a waste composition study in 1988 (Walker 1996). Lack of monitoring limits the management system's ability to respond to changes.

- **Origin of the wastes not known.** Current collection and information management systems do not allow for separation of residential and commercial/industrial waste. Identifying waste contribution from tourists and the cruise ship industry is particularly difficult. Recent changes in the information system provide for documentation of non-combustible waste tonnages, this may help to ascertain the quantity of construction debris in the waste stream.

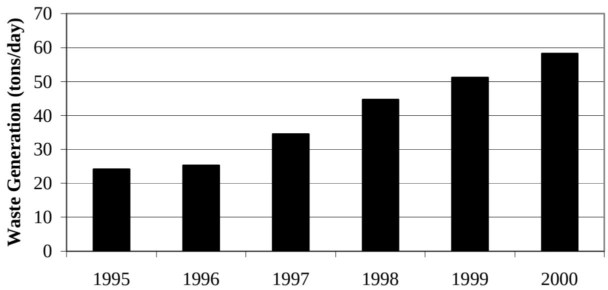


Figure 3: Growth in Average Daily Generation 1995 - 2000

(SWD 2001; 2000; 1998; 1997; 1996)

5.1Growth in Waste Quantities

The most discernible trend in Tortola's waste data is the substantial increase in quantity experienced each year since 1996. Annual generation of MSW increased by 140% from 8,818 tons in 1995 to 21,260 tons in 2000 (SWD 1996; SWD 1997; SWD 1998; SWD 2000; SWD 2001). Average daily receipts rose from 24 to 54 tons per day. Annual growth rate for solid waste receipts averaged 20% per year. As much as 100 tons per day may be delivered to the incinerator during peak generation times like Christmas, or after hurricane clean-up efforts. Maguire Group (2001a) projected that waste receipts would reach 40,000 tons/year by 2003, and 100,000 tons/year by 2008 if 20% growth rate continued. This forecast would be alarming for any planner in a situation where processing and disposal capacity are already constrained.

5.2Tourist Population Growth

Total visitor arrivals in the BVI increased at an average of 6% from 1991 - 2000 (Table 1). Cruise arrivals suffered a decline in the early 1990s, but showed stronger growth averaging 10% over the decade. A decrease in the absolute number of overnight visitors was experienced during some years, but average length of stay increased, and effective visitor population increased constantly throughout at an average rate of 10% (Table 2).

Additionally, the 1980s ratio of 60% water-based tourists (Encontre 1989) changed to *60% land-based* tourists during the 1990s as the phenomena of visitors staying in "own/friends" accommodations instead of hotels or yachts became more pronounced (Table 3). Land-based tourists not only generate more solid wastes than water-based tourists, they require higher use of the island's water, electricity, and transportation infrastructure (Dillon 1988).

Table 1: Visitor Arrivals in BVI 1995 - 2000 (Source: DPU 2001)

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Total Visitor Arrivals	365,340	412,032	365,668	392,290	484,056	474,185
% Change in Total Visitor Arrivals	11%	13%	-11%	7%	23%	-2%
Air Arrivals	*104,319*	*107,612*	*107,768*	*127,624*	*131,745*	*141,751*
Boat Arrivals	*138,967*	*144,820*	*153,036*	*159,524*	*171,597*	*178,949*
Cruise ship Passengers	*122,054*	*159,600*	*104,864*	*105,142*	*180,714*	*153,485*

Table 2: Effective Annual Contribution of Overnight Visitors to Tortola's Population3

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Average growth 1995 - 2000**
Total Overnight Visitors	4,390	5,060	5,556	6,423	7,362	8,128	13%
Hotel	1,371	1,508	1,752	1,332	1,627	1,494	-
Charter Boat	2,027	2,103	1,732	2,070	3,522	3,510	-
Rented Accommodation	42	47	56	39	80	76	-
Own/Friends Accommodation	950	1,401	2,017	2,982	2,133	3,049	-

(Source: DPU 2001)

[3] The formula used to derive these values is (number of visitors x average length of stay) / 365 (Scheu 1993; Dillon 1988).

Table 3: Visitor Distribution by Type of Accommodation (Source: DPU 2001)

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Average 1995 - 2000**
Overnight Visitors	219,510	243,683	244,318	279,097	285,858	303,565	-
Hotel	68,536	72,624	77,045	57,860	63,180	55,798	-
Charter Boat	101,360	101,288	76,147	89,951	136,744	131,076	-
Rented Accommodation	2,091	2,282	2,442	1,705	3,125	2,837	-
Own/Friends Accommodation	47,523	67,489	88,684	129,581	82,809	113,855	-
Average Length of Stay (nights)	7.3	7.6	8.3	8.4	9.4	9.8	8.5

5.2.1Tourist Impact on Waste Generation

> *"While there is a perception that the solid waste figures for land-based tourist operations are also higher than the domestic volumes generated, there is no quantitative evidence on which to base an analysis," (CEP 1997).*

Pantin (1999, 232) notes that "there are no readily available data sources that have been tracking the impact of tourism on solid waste generation." That assertion seems quite reasonable in light of the paucity of reliable solid waste data overall. Observations have been made that tourists staying in hotels generate up to twice as much solid-waste as local residents because they expect to sustain their higher material lifestyles even while away (UNEP 1999; World Bank 1995a; Scheu 1993), but little actual data exists (CEP 1997). Waste generation estimates from the literature of land-based, water-based, and cruise ship tourists are tabulated below.

Table 4: Land-Based Tourists Waste Generation Estimates

Source	**Estimate (kg/person/day)**	**Comments**
Scheu (1993)	1.10	"The majority of tourists stay in comfortable hotels and guest houses and therefore generate more waste than permanent residents"
World Bank (1995a)	1.16	"Stayover tourist solid waste, estimated to be double the residential waste generation on a per capita basis"
Walker (1996)	1.6	"Water-borne tourists tend to generate less waste than land-based"
Pantin (1999)	3.0	Average based on CTO study: St. Lucia - 3.1 Dominica - 2.3 Dominican Republic - 3.6

Table 5: Water Based Tourists Waste Generation Estimate

Source	**Estimate (kg/person/day)**	**Comments**
CMWMC (1993)	Cruise ship 1.77	After disposal of food waste into marine environment. Estimate used in OECS ship-generated waste project
World Bank (1995a)	Cruise ship 2.3 Yacht 1.6	Ship-generated estimates vary widely depending on the number of passengers, type of vessel and length of voyage
Campbell (1999); Blommestein and Williams (1994)	Cruise ship 3.5	"On average, passengers on a cruise ship each account for 3.5 kg of garbage daily – compared with the 0.8 kg each generated by the less well-endowed folk on shore"
CEP (1997)	Cruise ship 0.32 - 3.5	"The industry generates a higher per capita volume of waste than the domestic residential sector. PAHO (1996) estimates the per capita waste generation in Latin America and the Caribbean as 0.5-1 kg/person/day"

Table 6: Estimated Visitor Contribution to Tortola Waste Stream

Daily Estimated Contribution (tons/day)							
Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Comments**
Hotel	4.1	4.5	5.3	4.0	4.9	4.5	3.0 kg/ person/day
Charter Boat	3.2	3.4	2.8	3.3	5.6	5.6	1.6 kg/ person/day
Rented Accommodation	0.1	0.1	0.2	0.1	0.2	0.2	3.0 kg/ person/day
Own/Friends Accommodation	2.9	4.2	6.0	8.9	6.4	9.1	3.0 kg/ person/day
Daily Overnight Visitor Contribution to BVI Waste Stream	10.3	12.2	14.2	16.4	17.2	19.5	-
Daily Overnight Visitor Contribution to Tortola's Waste Stream	8.3	9.8	11.4	13.1	13.7	15.6	Assume 80% of visitors Tortola based (Walker 1996)
Annual Estimated Contribution (tons per year)							
Annual Overnight Visitor Contribution to Tortola's Waste Stream	3017.1	3572.8	4159.0	4780.3	5009.3	5685.6	-
Annual Cruise-Ship Contribution to Tortola Waste Stream	216.0	282.5	185.6	186.1	319.9	271.7	1.77 kg/ person/day, landing time 1 day
Total Estimated Annual Overnight Visitor Contribution (tons per year)	3233.1	3855.3	4344.6	4966.4	5329.2	5957.3	-

5.3Local Population Growth and Waste Impact

Census results for 2001 have not yet been published. Official projections based on the last census have employed a 2% annual increase. However, the literature has speculated that the 3.8% rate of growth experienced during 1980s seemed set to continue through the 1990s. Both population scenarios will be considered.

Table 7: Tortola Population Estimates (Walker 1996; Malone 1995; DPU 1994)

Year	**Rate of Growth**	
	2%	**3.8%**
1991	13,225	13,225
1992	13,490	13,728
1993	13,759	14,249
1994	14,034	14,791
1995	14,315	15,353
1996	14,601	15,936
1997	14,893	16,542
1998	15,191	17,170
1999	15,495	17,823
2000	15,805	18,500

Table 8: Estimated Local MSW Generation Rates for Tortola

Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Total municipal solid waste (tons/year) (from Table 6)	8,818	9,254	12,600	16,296	18,698	21,260
Total visitor contribution to waste stream (tons/year) (from Table 13)	3,233.1	3,855.3	4,344.6	4,966.4	5,329.2	5,957.3
Visitor contribution as a % of waste	37%	42%	34%	30%	29%	28%
Local contribution (tons/year)	5,585	5,399	8,255	11,330	13,369	15,303
Local average daily solid waste (tons/day)	15.3	14.8	22.6	31.0	36.6	41.9
Local waste generation (2% popln. growth rate) (kg/person/day)	1.1	1.0	1.6	2.1	2.4	2.7
Local waste generation (3.8% popln. growth rate) (kg/person/day)	1.0	1.0	1.4	1.9	2.1	2.3

**Local MSW refers to total contributions of residential, commercial, and institutional sectors.*

5.4Solid Waste in the Island System

These estimates of local waste generation rates are of course only as good as previous assumptions, and the solid waste data allow. However, if these assumptions do reflect Tortola's situation then, prior to 1997, visitor contribution accounted for a much more significant share of the MSW stream. In 1997, estimated local per capita generation rates increased substantially, and continued to increase. Local per capita rates more than doubled under both population scenarios, and in the case of 2.0% population growth, local waste generation of 2.7 kg/person/day would have approximated visitor waste generation in 2000.

To orient the waste management problem within the larger context of island sustainability, we need to picture Tortola's society as a social organism whose immediate environment is the island of Tortola. This social organism engages in economic activity to meet its needs. The earlier discussion of the thermodynamics of living systems established that sustaining this economic process or social metabolism requires inputs of low entropy materials from the environment, and results in the inevitable output of high entropy wastes to the environment. What becomes evident from an overview of material flows in Tortola is the gradual build-up of high entropy wastes in the domestic environment, a picture of an organism engaged in the process of fouling its own nest.

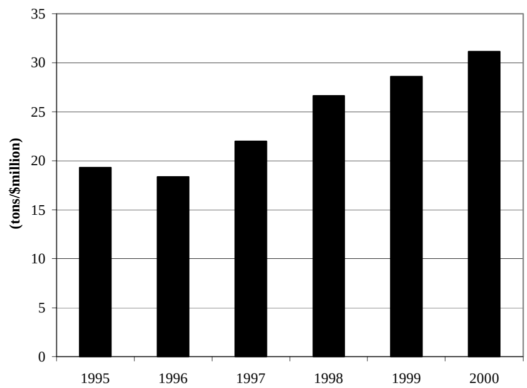


Figure 4: Municipal Solid Waste per Unit Economic Output

5.4.1 Solid Waste vs Economic Growth

Waste generation rates for the local population are influenced by increasing incomes and consumption. The BVI's economy expanded rapidly and consistently from 1991 - 2000. Gross Domestic Product (GDP) and GDP per capita respectively rose from $315 million to $680 million and $18,900, to $33,700 (DPU 2002).

Comparing waste and GDP, nineteen (19) tons of MSW per $1 million of GDP were generated in 1995. By 2000, thirty-one (31) tons of wastes were generated for $1 million GDP. This represents a 61% increase and indicates more materials flow per unit of economic output. Further, this suggests that Tortola's economy is becoming more materially inefficient, and in fact moving away from sustainability (Figure 4).[4]

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4 Studies of material flows through national economies have been published by the World Resources Institute [WRI] (Matthews *et al.* 2000; Adriaanse *et al.* 1997). A study of energy and material flows in a pre-industrial island economy was published by Singh *et al.* (2001). The underlying basis for these studies is the concept of industrial or social metabolism and

5.4.2Illustration of Material Flows

The BVI economy is not a producer of materials, but a producer of services. It does not extract raw materials from the earth and manufacture them into goods. The majority of materials used by the BVI's economy have been extracted and processed elsewhere and are imported into the country in finished or semi-finished form. Tortola's economic activity is driven by the consumption of material goods for the production services. Additionally, increased GDP/capita provided the BVI's local population with increased ability to satisfy consumption by importing desired goods.

Annual material imports to the BVI increased from $ 105 million in 1991, to $201 million in 2000. The cumulative import bill for 1995 - 2000 was in the vicinity of $1.02 billion (DPU 2001). For the same period, material exports (rum, sand, fish/meat) only totalled $137 million or about 13% of imports. The balance of trade underscores the assertion that **more materials are coming into the island system than leaving it** (Figure 5).

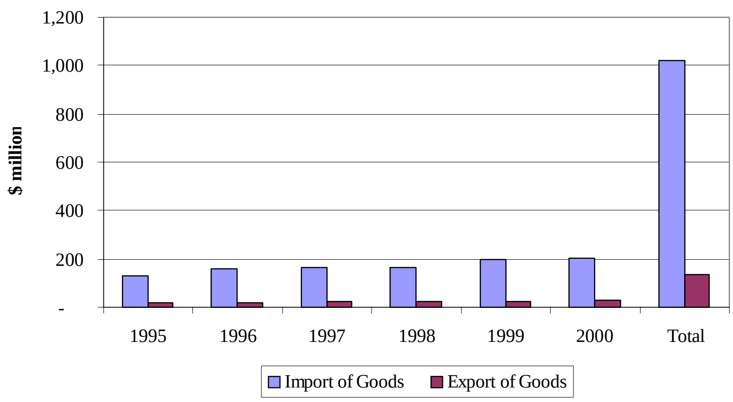

Figure 5: BVI Merchandise Trade Statistics 1995 - 2000

5.4.3 The Regional Context

Apart from incineration issues, waste management challenges faced by Tortola are typical for SIDS both regionally and globally (CSD 1999; Raj 1999; UNEP 1999; CSD 1998). Indeed, these challenges are typical of all countries globally (UNCHS 2001) but there still exists the unique context of SIDS.

Immediate finitude of land is perhaps the most obvious differences between SIDS and continental countries. Space constraints extend to land available for waste disposal and the "lack of a viable away as mainlanders might take for-granted," Hul (1989, 40). The crucial

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the fact that economies must be sustained by material flows. Knowledge on specific environmental impacts of many material flows is lacking, but the general assumption is that the amount of environmental pressure increases with the amount of material flow (Bringezu 1997).

implications of Tortola's small size for its waste management situation becomes apparent when compared to other islands in the Caribbean. Absolute quantity of Tortola's waste is quite small, but quantity relative to size is larger than all other OECS countries and Barbados (Figure 6). Bermuda exceeds even Tortola at 1,833 tons/km^2), having three times the population and one of the highest population densities in the world (Bermuda Online 2002). Although it too is 54 km^2, the terrain is flat which allows some small measure of choices that Tortola does not have. Supplementing their incineration program to reduce waste volumes, Bermuda also limits vehicle size, number of vehicles per family, and subsidizes the export of recyclables (Bermuda Online 2002; Walker 1996).

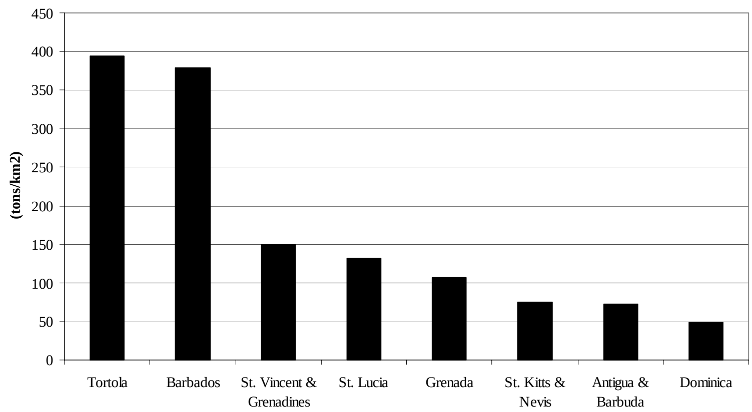

Figure 6: Relative Quantity of Municipal Solid Waste per Island

6 Analysis of tortola's situation

> *"The crucial point is that the economic process is not an isolated, self-sustaining process. This process cannot go on without a continuous exchange which alters the environment in a cumulative way," (Georgescu-Roegen 1976a ,4).*

A significant portion of what were low-entropy inputs to the economic system likely end up as high-entropy outputs (emissions, effluent, and solid-wastes) to the domestic environment within a year (Matthews *et al.* 2000[5]). Materials retained in the economy for longer periods are those in the form of infrastructure and durable goods. These are considered "stock" materials. Eventually, stock materials also end up as waste, when buildings are demolished or when long-lived items such as furniture reach the end of their useful lives. Emissions (e.g. CO_2), waste heat, and effluents eventually dissipate into the global environment (atmosphere and ocean). What is occurring overall is a gradual build-up of material entropy, in the form of solid-wastes, within the boundaries of island system.

6.1 Environmental Implications

The domestic island environment has limited waste assimilation capacity (Singh 1996). In the long term, there simply is not enough ecologically suitable and socially acceptable land

[5] Matthews *et al.* (2000, xi) found that "one-half to three-quarters of annual resource inputs to industrial economies are returned to the environment as wastes within a year."

available for large disposal facilities. The actual environmental effect (and consequently human health) of incinerator emissions, leachate from ash and other landfill materials has not been ascertained. Emissions will increase when incinerator capacity is expanded.

The storage and collection system at present has just enough capacity to handle the island's waste. Further substantial increase in solid waste quantities would require the deployment of more waste receptacles, and increased collection service (already daily in many parts) to keep pace with demand for disposal services. Finding acceptable sites for collection bins amidst increasing residential, commercial, and other infrastructure developments is as challenging in its own right as finding a suitable landfill location. It is not difficult to imagine that growing waste quantities could at some point overtax either the storage and collection systems leading to visible pollution, odour, and aesthetic degradation in the area of storage facilities. Additionally, overflowing storage bins would encourage proliferation of vermin,[6] posing a health risk to the population.

6.2 Economic Implications

The observed trend of increasing solid waste output per unit of GDP (Figure 15) is cause for concern. This trend has been typical for world economies but Matthews *et al.* (2000, v) reflect, "as long as continued growth in economic output implies continued growth in material inputs to and waste outputs from the economy, there is little hope of limiting the impacts of human activity on the natural environment." Industrial countries are attempting to 'decouple' economic activity from material throughput/environmental pressure, i.e. attain economic growth while generating less waste because of increased resource and energy productivity (OECD 2002a). There is no reason to believe that island economies are somehow exempt from needing to 'decouple' their economic activity from material throughput as well.

Singh's (1996) consideration of the entropic nature of economic processes led him to urge island economies to specialize in knowledge based economic activities rather than material and energy intensive activities like manufacturing. Their small size, limited resources, and fragile life support systems of small island states, he argues, simply cannot continue to absorb the excessive quantities of wastes caused by material intensive throughput economies. In that case, perhaps Tortola's movement towards financial services is a step in the right direction.

6.2.1 Tourism Carrying Capacity

Tourism though, despite falling behind the financial services industry in contributions to the national budget, is still Tortola's main employer (Coopers and Lybrand 1996). Capacity of the waste management system provides one dimension to answering the question of population/tourism carrying capacity. If the capacity of the waste disposal system is determined by incineration capacity, then assuming priority is given to the domestic population, the more waste generated by the domestic population the less capacity available to support tourism activities.

In 1995 and 1996, there was enough incinerator capacity on Tortola for both locals and tourists. But substantial increase in local contribution to the waste stream meant that capacity to support tourist wastes declined. In 2000, local waste contribution of 41.9 tons per day accounted for all of the island's incineration capacity, leaving no capacity to process tourist waste contribution of 15.6 tons per day. One could probably define a general formula, that tourism carrying capacity is a function of total waste management capacity minus domestic

[6]Also, in the tropics, mosquitoes which can carry dengue fever breed in the standing water which collects in discarded items.

waste demands. Something like:

Tourism carrying capacity = F (total solid waste capacity - domestic solid waste)

The number of tourists that could be served by tourism capacity would then depend on the relative mix of water-based, land-based, and cruise ship visitors.

6.2.2 Financial Sustainability

Finally, financial sustainability of the waste management system itself is also a question. At present, Government funds the bill for cleaning up after 16,600 - 18,500 people from the general revenue. Constructing another incineration facility will further increase demands on the public purse, which already pays more than $1.5 million annually to provide solid-waste service. As Pearce and Turner (1993) indicate, when the public does not perceive the costs of waste management, they tend to undervalue the environment's assimilative capacity. If public generation continues to increase because the public is not provided with any incentive to reduce, and Government does not increase funds to the solid waste system because of other demands on its budget, then effectiveness of the service will decline and lead to the visual pollution and aesthetic degradation discussed earlier.

6.3 Socio-political Responses

> *"The cost for cleaning up after an undisciplined citizenry is enormous," (Cointreau 1989, 3).*

To date BVI has not instituted any national waste minimization, reuse, or recycling policies. Taking a systems perspective, it is obvious that the solid waste stream depends on the type and quantity of goods that are imported into the island. Yet there have been no attempts to monitor, limit, or regulate the materials entering the island system that prove to be a waste disposal problem.[7]

Although there are no explicit waste management policies, there are national policy goals which support promotion of a more comprehensive, systems-based approach to solid waste management. These include the Mission Statement of the National Integrated Development Plan (BVI 1999):

> *To mobilize and deliver resources to ensure the* ***health****, productivity, prosperity, cohesiveness, and resilience of the people in a responsible and integrated manner*

And its stated development goals:

- To ensure environmental sustainability
- To attain global competitiveness

Solid waste is the major terrestrial pollutant in Tortola. It also contributes to the marine pollution burden. Within the island system, build-up of solid waste results in increased material entropy in the system and arguably reduces the availability of low-entropy "aesthetic resources" which are the basis for the island's economic activity, tourism. In absolute terms,

[7] There was an aborted attempt to implement an upfront fee for the recovery of end-of-life vehicles.

the amount of waste for disposal on Tortola is rather small. In relative terms the amount of waste presently generated is a problem, considering the present scarcity of disposal capacity that is environmentally, economically and socially acceptable, a situation likely to worsen with time. Unrestricted growth in waste quantities could prove disastrous, effectively overwhelming the social and economic capacity to handle wastes, and the island ecosystem’s ability to assimilate wastes. This situation is clearly recognizable as unsustainable (Eckman 1993), and clearly conflicts with national goals to ensure health, environmental sustainability, and global competitiveness.

7 Addressing the waste problem

Many countries are realizing that application of technology (incineration, better landfills, etc.) to the waste disposal problem is not a permanent solution in the face of rising population, consumption and waste generation. Incineration, and even materials recovery, recycling, and re-use, are "end-of-the-pipe strategies" to deal with waste after it has been generated. This has been recognized for decades, but even so, most developed countries are still only in the initial stages of mobilizing to prevent waste generation in the first place (OECD 2002b; 2000).

A crucial thing to realize is that small islands with economic profiles similar to Tortola are consumer societies and have no control over production processes. The environmental burden posed by their material flows depends heavily on the products their populations import into the island ecosystem. Instead of having to address both production and consumption, many SIDS can direct their limited human and financial resources towards modifying consumption habits. Price and Joseph (2000, 97) urge that "a start must be made on changing the nature of demand itself so that consumers think before buying or using. It will take a generation for a cultural change of this magnitude to take effect and its introduction will depend on changes in education, presentation and perception." The efforts of the Solid Waste Department to educate the public need support from national policy and should be considered a matter of urgency. Monitoring the composition of materials in the waste stream will provide information on whether material recovery policies are successful.

Waste prevention targets should be set. In this instance, perhaps planners and policy-makers will be more amenable to working backwards. That is, a maximum quantity of waste for disposal (e.g. 36,500 tons per year) should be determined based on the amount of incinerator capacity and landfill space Tortola is willing to invest in both now and in the future. Assessment of the connection between material flows and waste generation can form the basis for such analyses. The obvious conclusions for such analyses are that the present quantities of waste are problematic, further increases are undesirable, and some level of reduction through waste prevention, recovery, re-use, and export is necessary.

Increasing incineration capacity is not an ultimate answer. As has already occurred less than a decade after commissioning the first plant, continued population growth and consumption will offset any gains in waste management effectiveness. A national commitment to waste reduction must be made.

7.1 Information for Decision-Making

Both waste managers and policy-makers need reliable indicators to assist them in making informed decisions, and to assess the island's progress towards or away from possible sustainable futures. Monthly and yearly waste receipt data is compiled by the SWD. Correlated with the weight of materials imported into the island it would provide an invaluable resource. For example, using the monetary value of imports 1990 - 1993 Walker

(1996) predicted an upper estimate of 3.8 million bottles (of which 2.5 million beer bottles) were imported into Tortola during 1996. These 3.8 million bottles would have been the source of the estimated 1,700 tons of glass received in the waste stream during 1996. For the time being, this case is merely illustrative, however, one can imagine the tremendous analytical value if the weight of glass and other materials imported[8] was also compiled in the national statistics. The average retention time of glass in the Tortola economy could be determined. Contribution of littered glass bottles to aesthetic pollution burden could be derived, based on how much of discrepancy between glass imported vs. glass disposed remains unaccounted (i.e. not in inventory). Without data on material inputs and outputs, the financial records of trade cannot provide a complete picture of Tortola's economic situation, and its sustainability position.

Single island countries would provide excellent candidates for this type of study as national material accounts, once compiled, could be applied without further ado. In an archipelagic state like the BVI, separate material accounts for all islands would be necessary and this may provide some additional challenge to limited human and financial resources. Presently BVI statistical information is aggregated at the national level, however, the national integrated development plan lists equitable development on all islands as an objective. In that respect I would argue that separate financial and material accounts need to be kept for each island. Otherwise, the territory simply falls victim to treating the sister islands as appendages to the economic activity on Tortola.

On the output side of the equation, a solid waste management system which is only allowed to get involved when materials exit the economic system, constantly remains at a disadvantage (Price and Joseph 2000). Garbage is not something which arises in isolation, but as a result of the sum of all economic activity within the island. Solid waste managers must be aware of the material diet of their island economy and a reciprocal relationship needs to develop between island economic managers and waste managers. Information on imports is necessary for medium-term planning by waste managers, so they are not surprised by changes in the complexity of the waste stream. Information on solid waste receipts can provide economic managers with a concrete measure of economic activity as it occurs. The solid waste department will know, long before the statistics department compiles their analysis, whether a tourist season has done well or poorly. Their evidence is tangible, the day to day receipts of garbage.

7.2 Utility of Waste as an Indicator of Sustainability

Solid waste is capable of providing insights on environmental (i.e. land use, pollution), economic (i.e. increased throughput, tourism carrying capacity), and social aspects of sustainability (i.e. policy intervention) on the island Tortola. Therefore, monitoring the quantity and complexity of the solid waste stream provides the means to judge the pollution burden, level of economic activity, and eventually public compliance with policies if they are implemented.

In Tortola, the quality of solid waste data for these analyses could be improved by addressing public compliance with Solid Waste Department procedures, weigh scale maintenance, and staff co-operation. Utility could be improved by conducting further studies to determine present composition of the island's waste, the rate of waste generation in residential, commercial, and institutional sectors, and the actual tourist contribution.

In order to enjoy the full power of waste as an analytical tool for assessing progress

[8] Although for this case what one would require is the weight of bottles when empty.

towards sustainability, however, the connection between waste and material inputs to the island's economy must be made. The thermodynamic properties of open-systems such as human beings and their economies necessitates that a continuous flow of raw materials and wastes to and from the environment be maintained. It is in this area of materials, wastes, entropy, and the economic process that questions about physical sustainability must be answered (Costanza *et al.* 1997; Bringezu 1997; Ayres 1994).

Tortola's quantitative records on waste receipts provide an important starting point for sustainability analysis. Developing records of direct material inputs to Tortola's economy is the next step. In the short term, material flow analyses for easily identified problems like glass, wooden pallets and tyres should be compiled. In the long-term, full material accounts for the island should be developed.

At a minimum solid-waste and material indicators for the national database should include:

- Quantity of solid waste received, broken down into:
    - Quantity of waste incinerated/not incinerated
    - Quantity (volume) of ash/waste for final disposal
    - Composition of waste stream (paper, glass, plastic, metal, bulky goods, etc.)
- Direct material input to the economy, broken down into:
    - Domestic input (quantity and type of materials)
    - Imports (quantity and type of materials)

Records on the first three are already being kept by the SWD. Composition of the waste stream and direct material input to the economy would have to be determined. Thus, some effort is required, but developing a basis to assess physical sustainability should be well within the reach of BVI's human and financial resources.

7.3 Further Study

The analyses in this study were based upon waste generation estimates from elsewhere. An effort should be made to assess the situation as it actually stands in Tortola. To this end, further research should occur in the following areas:

- Determining the actual quantity and composition of wastes from residential, commercial, and institutional establishments.

- Determining actual waste generation rates for various segments of the tourist population. Also, number of cruise ships discharging wastes and the quantities landed.

- Determining composition and quantity of wastes generated by various sectors of the economy (financial services, wholesale and retail, construction, etc). Identifying and implementing strategies to deal with problem wastes from specific sectors (ink, copiers, computers, packing crates, etc.).

- Assessing direct material inputs to Tortola's economy. This would require some disaggregation of information in the national statistics. Efforts to do this should be undertaken in any case, as one of the NIDS goals is to ensure balanced development across all the islands. Without separate accounts, it would be difficult to properly monitor development on all islands.

8 Conclusions

Voices of Caribbean small island developing states (SIDS) have been mostly silent on the international debate of assessing *physical* progress toward sustainable development. This is unfortunate because the island system presents a natural boundary within which to study environment-economy-society interactions at the heart of making progress towards sustainability. Correspondence of natural and political boundaries, and the smaller scale of social and political structures offers the promise that sustainable development research in SIDS will be less complex than in continental areas. SIDS research also promises to be meaningful at a global level. Limited human and financial resources in SIDS still inhibit their capacity to conduct research and implement its results. Even so, SIDS must somehow face the challenge.

Solid waste management should be one of the priority areas for the development of sustainability indicators in small island states. Focussing on waste provides insight not just on pollution concerns but provides a point from which to consider holistically the whole of economic and social processes as well. Solid waste is already a priority issue on the agenda of Caribbean and Pacific SIDS (UNEP 1999; UN 1994). Wageningen and Wade (2000) have argued that neither special skills nor equipment are needed to collect waste monitoring data that would show progress on improved waste management practices to national governments. Efforts to address the waste management situation, then, should not be pursued in isolation. They should be tied to the larger context of national sustainability. Caribbean SIDS need to begin putting themselves in a position to answer questions about their limits, carrying capacities, and physical dimensions of sustainability.

Solid-waste was found to be a feasible indicator for use in assessing physical progress towards sustainability. Its utility rests on an understanding of the thermodynamic nature of the economic process (Tsuchida 1999; Costanza *et al.* 1997; Binswanger 1993; Georgescu-Roegen 1976a; 1976b). Entropic wastes are an inevitable by-product of the material flows needed to sustain the metabolism of open-systems such as human economies. Reduction in wastes would reflect less environmental pressure associated with material flows.

Solid waste has become an increasing pollution burden in Tortola as a consequence of development and economic growth. A 40 ton per day incinerator commissioned in 1994 was expected to serve the island's waste management needs for well over twenty years. However, incinerator capacity was surpassed by 1998; a mere four years after it was commissioned. Annual solid waste receipts increased from 8,818 tons (24 tons/day) in 1995 - 21,260 tons (58 tons/day) in 2000.

Major trends identified in Tortola for the period 1995 - 2000 were a 20% annual increase in waste receipts and an increase in local per capita generation rates from an estimated 1.1 or 1.0 kg/person/day to over 2.0 kg/person/day. Estimated annual tourist contribution to Tortola's solid waste stream increased from an 3233 tons (8.3 tons/day) to 5957 tons (15.6 tons/day). However, tourist contribution as a percentage of the waste stream fell from 37% to 28%, as estimated local waste generation increased from 5,585 tons (15.6 tons/day) to 15,303 tons (41.9 tons/day).

Comparison of waste generation with GDP indicated that waste per $million economic output increased from 19 tons in 1995 to 31 tons in 2000. Thus, Tortola's economy exhibits a typical trend of increased economic activity tied to increased material flows. Monetary volume of merchandise trade indicated constant growth in imports with $1.02 billion imported goods versus $132 million exported goods over the 6-year period, illustrating a build-up of materials in the island system. Most of these materials are expected to have ended up in the waste stream within a year of their importation (Matthews *et al.* 2000).

Absolute quantities of waste in Tortola are small, however, quantity relative to size of the island was found to be quite large. In fact, Tortola's waste relative to size was larger than all other OECS islands and Barbados. Allowing unrestricted growth in solid waste was shown to contradict national policy goals to ensure health, environmental sustainability, and global competitiveness.

Exploration of the utility of waste as an indicator led to the conclusion that solid-waste can provide information on the environmental aspect of sustainability, and also economic and social issues relevant to that aspect. However, its true power as an indicator for physical assessment of sustainability arose from its use in conjunction with information on material inputs. Both these indicators are necessary to develop a true understanding of the physical basis of the economic process within the island. Material input data is not presently available in the BVI and recommendations are made for its compilation and inclusion in the national statistics.

Integrating waste data into national statistics provides policy-makers with more balanced picture of the island's position in relation to sustainability. Tortola's quantitative data on waste receipts puts it in a good position to begin developing an accurate picture of material flows in the island system. In doing this, it would be blazing a methodological trail for other Caribbean island countries to follow in assessing progress towards sustainability.

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