Wastewater Treatment Plants Monitoring Programme 2005

ENVIRONMENTAL PROTECTION OFFICER
ENVIRONMENTAL PROTECTION DEPARTMENT
MINISTRY OF HOUSING, LANDS AND THE ENVIRONMENT
JEMOTTS LANE, ST. MICHAEL
BARADOS
January 2006

Table of Contents

1 Overview

1.1 Objectives

1.1.1 To carry out a survey of the existing wastewater treatment plants in Barbados

1.1.2 To assess the level of treatment being achieved by treatment plants across the island.

1.1.3 To perform a preliminary grading exercise for wastewater treatment plants.

1.2 Methodology

1.2.1 Grab samples were taken from each of the wastewater treatment facilities in Barbados. Three (3) samples were taken from each treatment plant. Two samples were taken from the effluent and one from the influent (See Table 1).

Table 1: Sample Taken From Each Treatment Facility

		Sample Location	
Analyses	Sample Volume	Influent	Effluent
Chemistry	500 ml	√	√
BacT	100 ml	×	√

1.2.2 The samples were collected using a sludge judge, stored in a cooler at approximately 4°C and transported[1] to the Government Analytical Services (G.A.S) laboratory where analyses for the parameters listed below were performed:

Chemistry

- Total Nitrogen (TN)
- Chemical Oxygen Demand (COD)
- Biological Oxygen Demand (BOD)
- Dissolved Oxygen (DO)
- Total Kjeldahl Nitrogen (TKN)
- pH
- Total Phosphorous (TP)
- Total Suspended Solids (TSS)

BacT

- Faecal Coliform (FC)
- Enterococci (ENT)

1.2.3 In conjunction with the sampling of the treatment plants, a survey was carried out via the use of questionnaires to solicit general information about these facilities. The information collected included existing sampling procedures; sludge disposal practices; operator qualifications and the disinfection and disposal of the effluent (both liquid and solid).

[1] The samples were transported to the lab in a time such that the period between sample collection and analysis by the laboratory did not exceed six (6) hours.

1.2.4 This data along with the laboratory results were inputted into a Microsoft Access database from which charts and statistical tables were generated.

2 Survey Analysis

2.1 Summary of Analysis

2.1.1 There were collectively thirty wastewater treatment plants in existence in Barbados situated at twenty-eight locations. Of these, samples were not taken from three locations which are identified in Table 2.

Table 2: Closed Establishments for 2005

Location	Reason Not Sampled
Airport	Not commissioned as yet
Mango Bay	Hotel closed for major renovations from May 1, 2005 for approximately 6 months
SandPiper Inn	Hotel is under renovation

2.1.2 Of the remaining twenty-seven (27) plants only twenty-five (25) were surveyed. Efforts to retrieve questionnaires issued to the Savannah and Sandy Lane Hotels were unsuccessful up to July 22 2005, when report writing had commenced[2].

General Information

2.1.3 It was found that the average age of the plants in Barbados was 7.6 years; whereas the oldest plant, the Bridgetown Sewage Treatment Plant, was twenty-three years old.

2.1.4 The bulk of the treatment plants implemented secondary treatment as shown in Figure 1. Secondary treatment is a biological treatment process

[2] Despite the fact that not questionnaires were obtained from the Sandy Lane and Savannah Hotels, samples were still taken from these facilities and analysed.

that removes dissolved organic matter from wastewater. The wastewater comes into contact with micro-organisms which aerobically utilize organic matter from sewage as their food supply. Consequently BOD and COD are the main parameters affected by this type of treatment as these are both indicators of the quantity of organic material present.

2.1.5 One waste treatment plant utilised ultra-filtration. Ultra-filtration not only reduces BOD and COD but also TSS. Ultra-filtration is a low-pressure membrane process used to separate high molecular weight compounds e.g. organic compounds from a feed stream. In contrast one (1) plant, namely the South Coast Treatment Plant, utilized preliminary treatment which only serves to remove suspended solids and greases from wastewater. Hence this type of treatment for the most part only lessens suspended solids.

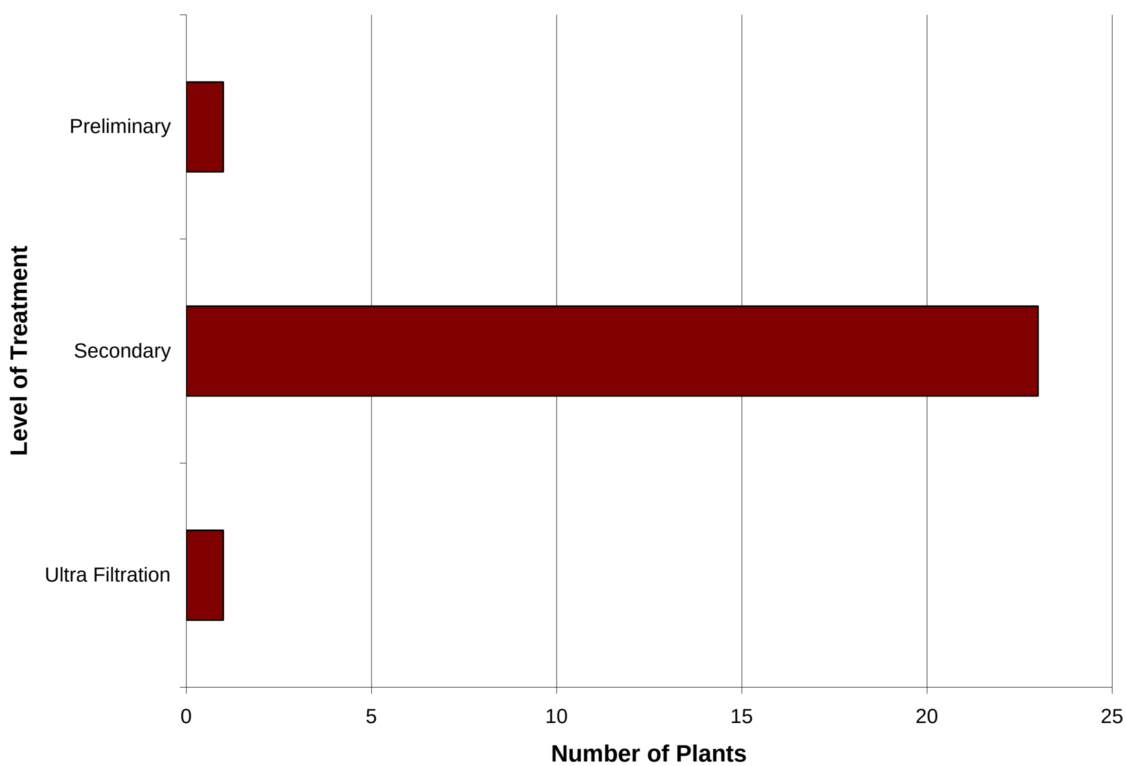


Figure 1: Number of Plant Categorized by Level of Treatment

2.1.6 Another observation that was made was that only four (4) of the twenty-five (25) plants surveyed had their plumbing colour coded or effectively labelled so that officers could easily follow the flow of waste through the facility. Appropriate colour coding or labelling is essential and thus it is recommended that a colour coding system be established by the Barbados National Standards Institute for wastewater plants.

Sampling Procedures

2.1.7 Furthermore 68% of the plants surveyed had a sampling programme and of these approximately 88% kept records of sampling activities and results. Typically the majority of locations sampled every 2 – 4 months, mainly for BOD and TSS. Only one location tested for FC and Mixed Liquor Suspended Solids (MLSS).

Operator Information

2.1.8 It was further observed that only two wastewater plants, the Bridgetown Sewerage Treatment Plant and the South Coast Treatment Plant, had operators on site. For the remaining plants, if a problem occurred the company or person responsible for the plant was called to address the situation.

Plant Maintenance

2.1.9 Approximately 65% of the plants kept records of maintenance activities. Furthermore it was found that maintenance was normally performed as necessary. However, a large proportion of plants still performed daily or weekly maintenance checks. However, the exact nature of these checks was not ascertained.

Sludge Disposal

2.1.10 Most of the plants indicated that their sludge was disposed as needed. Figure 2 shows that most of the plants disposed of their waste to the Bridgetown Sewage Treatment Plant, while two plants had their solid waste (sludge) landfilled; one at Spencers and the other at the Mangrove Pond landfill[3]. The plants whose disposal was classified as Not Applicable (N/A) belonged to residences and to date those plants have not generated enough sludge to be disposed. However, it was implied by the maintenance person that when disposal did become necessary the sludge would be sent to the municipal plant.

2.1.11 One facility, namely the Foursquare Rum Distillery, shipped it sludge to the USA where it is used as raw material for fertilizer production.

2.1.12 When the sludge was disposed in Barbados, Greening Sewerage Inc. followed by D&D Septic Services, were the most popular choices for the solid waste management as illustrated by Figure 3.

2.1.13 It should be noted that where records were kept, these recorded housed at the office of the company responsible for the wastewater plant.

[3] The South Coast and Bridgetown Sewage Treatment plant disposed of its solid waste at the Mangrove Pond Landfill and Spencers respectively.

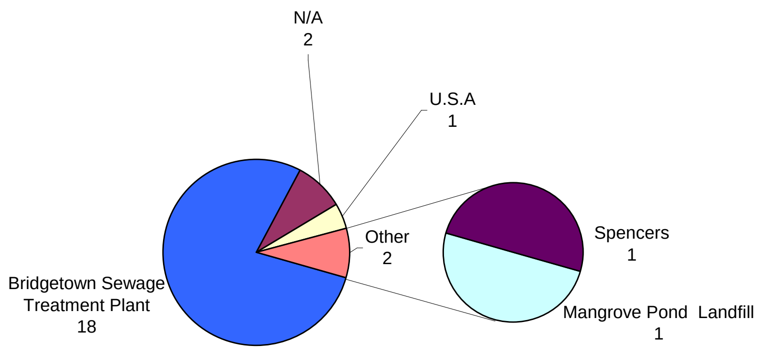


Figure 2: Disposal Methods

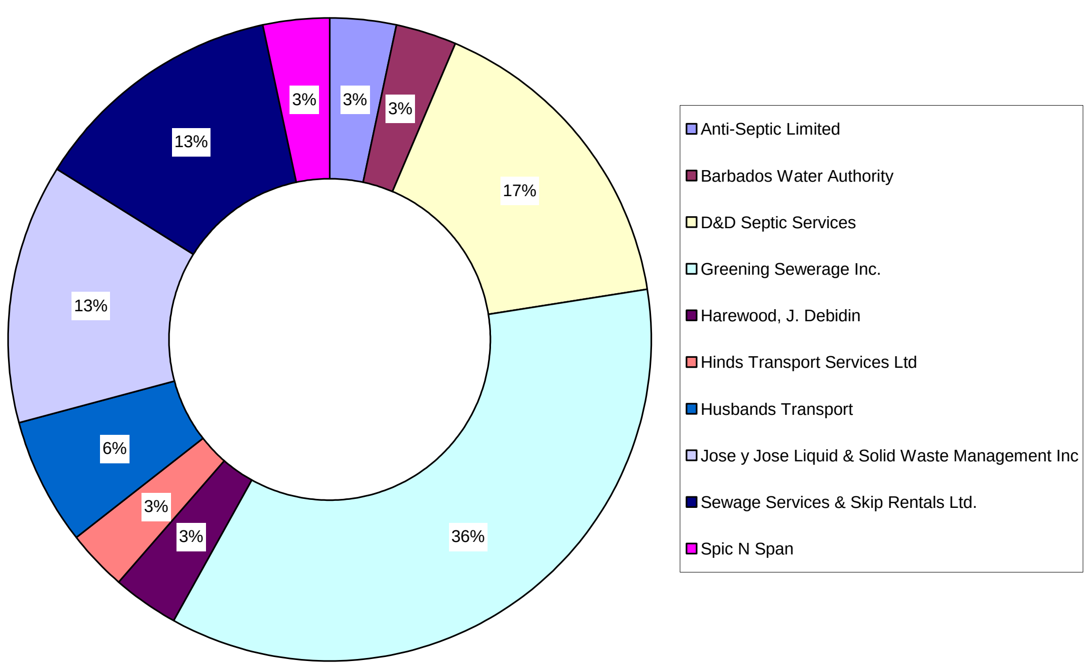


Figure 3: Utilization of Disposal Companies

Effluent

2.1.14 Twenty-two of the twenty-seven treatment plants indicated that they disinfected their effluent (21 by the use of chlorine and the other by means of ultra-violet radiation). However, only seven (7) of these plants had disinfection systems that were operable at the time of the inspections; the disinfections mechanisms at the remainder were defunct.

2.1.15 The vast majority of treatment facilities discharged all of their liquid waste to suck wells (See Table 3). A few used their effluent for irrigation purposes or to flush toilets[4], while others discharged part of their effluent and used the remainder for irrigation. Of those that reused their effluent three locations, namely the Coral Reef Club, Almond Beach Village and Reeds House, indicated that they colour coded or labelled the pipes conducting the effluent water. However, there was no signage indicating that wastewater was being reused.

Table 3: Fate of Effluent from Treatment Plants

Effluent Discharged or Reused?	% Plants
Both	24%
Discharged	60%
Reused	16%

[4] The Savannah Hotel was the only location that indicated (verbally during the inspection) that they reused their effluent to flush toilets within the hotel. All other establishments that reused their effluent used it for irrigation.

3 Water Quality Parameters

3.1 Overall Summary

3.1.1 It was found that, of the treatment plants in operation during 2005, there was an overall average decrease in the level of contaminants from influent to effluent except with respect to dissolved oxygen and pH (See Appendix A – pages I to II).

3.1.2 The large standard deviations of these parameters were indicative of the extensive fluctuations in the pollutant levels from one treatment plant to the next. Only pH showed a level of consistency from one facility to the next (See Appendix A – pages I to II); this is signified by the small standard deviations.

3.1.3 It was observed that the majority of treatment facilities showed compliance to the proposed Marine Pollution Control Act (Discharge) Regulations 2005 - End of Pipe Discharge Standards. Approximately 70% and 50% of the plants were compliant with respect to the standard of BOD and COD[5] respectively (See Appendix D for list of standards). In contrast Figure 4 shows that over 90% of the plants failed to be in accord with the standard for TP. In contrast only 44% of the plants complied with the standard for TSS.

[5] The standard for COD is taken from the website of the National Environmental & Planning Agency (NEPA) in Jamaica http://www.nrca.org/business/guidelines/effluent/SewageEffluentStandards.pdf Last accessed 25 July 26, 2005.

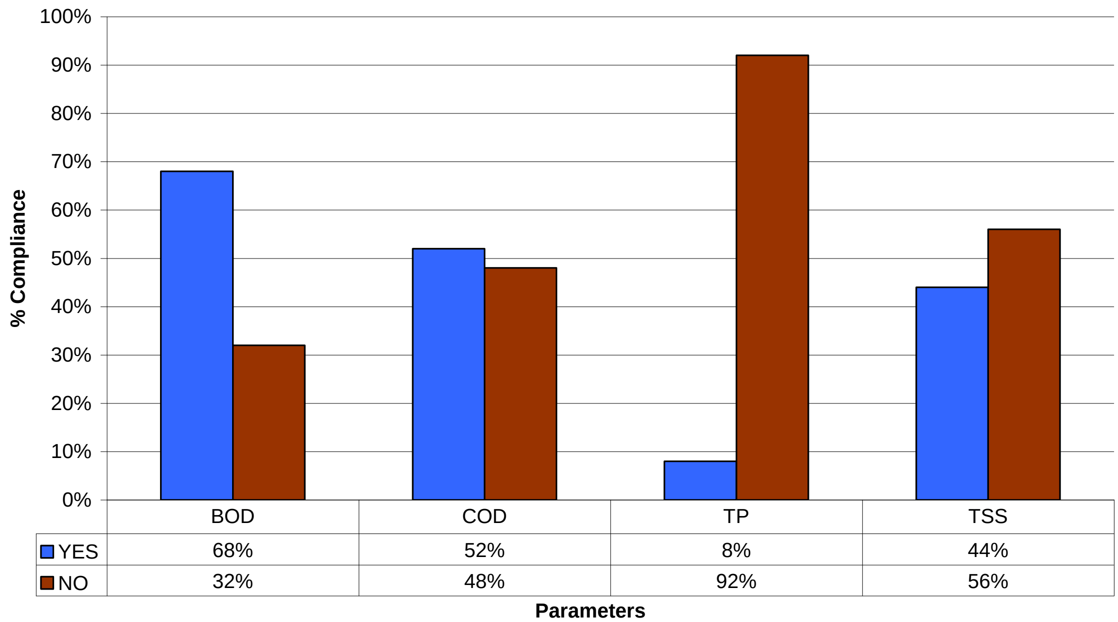


Figure 4: Percentage of Complaint Facilities for Select Parameters

3.1.4 The substantial number of plants that failed with respect to the guidelines for TP was expected since TP is typically only removed by treatment plants that employ tertiary treatment. An analogous result would also be expected for TN since TN is also primarily removed by tertiary treatment. However due to problems with the equipment at the G.A.S laboratory TN could not be analysed. Thus TN could not be included in this report.

3.1.5 With respect to bacteriological parameters the averages for Enterococci and Faecal Coliform were found to be 1.48 x 10^5 and 1.49 x 10^6 CFU[6]/100 ml respectively and exhibited standard deviations of 4.51 x 10^5 CFU/100

[6] CFU – Colony Forming Units

ml for Enterococci and 3.42 x 10^6 CFU/100ml for FC. These large standard deviations are indicative of the wide fluctuations in effluent bacteriological values from one plant to the next. Such fluctuations could be accounted for by the fact that some locations chlorinated their effluent, which would have substantially reduced the number of micro-organisms in the effluent, while others did not disinfect their waste.

3.1.6 Additionally, it should be noted that many of the bacteriological samples were taken from tanks that would have contained effluent from more than one day. In cases where these tanks were not chlorinated, this could have facilitated a sufficient incubation period for the bacterial population to multiply contributing to the high bacteriological average observed. As a result there are negative implications for the use of this data in enforcement activity.

3.1.7 It should be noted that no comparison to standards or guidelines was performed for Enterococci. This was because the sampling programme did not conform to the requirements established in the Marine Pollution Control Act of five (5) samples over a thirty day period.

3.1.8 Similarly, no comparison to regulatory guidelines was performed for Faecal Coliform as no suitable guideline could be identified. The proposed End of Pipe Discharge Standard under the Marine Pollution Control Act could not be used as it required that the measured FC value be compared to the geometric mean of a minimum of five (5) samples over a 30-day period. Since only one (1) sample was taken comparison to this standard was not possible.

3.1.9 In light of points raised in sections 3.1.7 and 3.1.8, the Environmental Protection Department needs to establish a single discharge limits for these parameters. If these limits are exceeded a more comprehension assessment of the plant would be warranted.

3.1.10 The mean BOD, COD, TKN, DO and TSS values for 2004 and 2005 were compared statistically using the Mann-Whitney test (See Appendix B). From the test it was concluded that the arithmetic means of these pollutants in the effluent for 2004 were greater than or equal to their means in 2005. This implies that quality of effluent in 2005 appeared to be the same or better than that in 2004. Possible reasons for this might have been:

- More efficient operation of the wastewater plants in 2005 than 2004
- Less concentrated influents

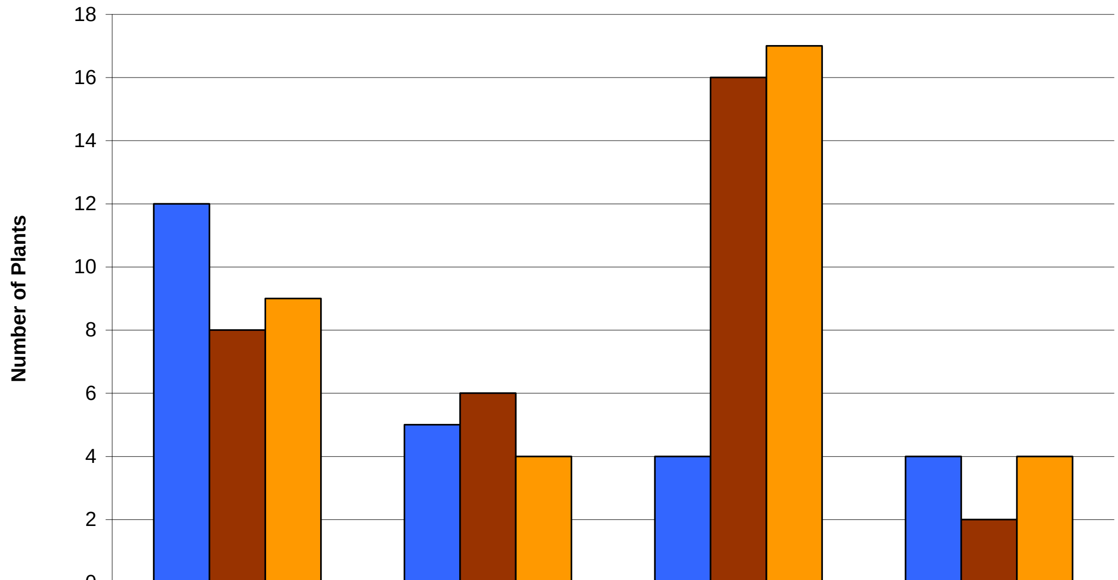
3.2 Individual Summary

3.2.1 For each location the removal efficiency was calculated using Equation 1.

$$\text{Removal Efficiency}(\%) = \frac{\text{Inlet Concentration} - \text{Outlet Concentration}}{\text{Inlet Concentration}} \times 100$$

Equation 1: Formula Used for Calculating Removal Efficiency

3.2.2 The removal efficiency speaks to how well the plant is treating a particular pollutant. With reference to Appendix A: page I – VI and Figure 5 below it is observed that the majority of plants had BOD removal in excess of 90% while most of the facilities had COD and TSS removal efficiencies between 0 – 49%.



	>90	89 - 50	49 - 0	<0
BOD	12	5	4	4
COD	8	6	16	2
TSS	9	4	17	4

Figure 5: Number of Plants with Percentage Pollutant Removal

3.2.3 This high proportion of plants that achieve TSS and COD removal between 0 – 49 % is of concern since most of these facilities utilize secondary treatment which should remove up to 80% of TSS and COD in the influent streams. High values of TSS in the effluent can smother coral and other marine vegetation if the effluent is discharged directly to the marine environment. Similarly, effluent high in COD can have a detrimental impact on the environment. COD is commonly used to indirectly measure the total amount of organic compounds in water. Organic compounds require oxygen to decompose and therefore reduce the amount of free oxygen for respiration. Consequently, there may be fish kills and/or degradation of the marine environment.

3.2.4 It was noticed that some plants had removal efficiencies that were less then zero. From Equation 1, this occurs if the effluent concentration is greater than the influent concentration. Possible reasons for this phenomena are threefold:

- The fact that some of the samples were taken from tanks which could contain effluent from previous days and/or
- Malfunction of the treatment plant resulting in poor treatment
- Wash out of solids from the clarifier or biological chamber into the effluent stream. This is dependent on the specific arrangement of the wastewater plant.

4 Plant Grading

4.1 Overview

4.1.1 Plant grading involves inspection of various parameters at a plant. These parameters are numerically coded and combined with weighting factors to obtain an overall percentage, representative of the plant's performance. Based on this percentage the plant is then placed in a class. The class determines what license the plant should be issued. Plant grading will be incorporated into a licensing system for wastewater plants.

4.2 Methodology

4.2.1 The inspection of each plant was divided into three categories:

- **Plant equipment** – this is an inspection of the plant to assess the general sanitation of the plant, whether the plant had its pipes labelled or colour coded or if the plant had any obviously malfunctioning equipment (See Table 4),

Table 4: Parameters Vetted During Inspection of Plant Equipment

Inspection Parameter
Colour Coding
General sanitation

- **Water quality examination** – comparison of critical pollutant levels in the effluent to standards (See Table 5 for parameter and Appendix D for Standards),

Table 5: Parameters Vetted During the Examination of Water Quality

Parameter
pH
BOD
COD
TSS

- **Document Inspection** – identification of, among other things, the number of times maintenance is conducted and the procedure for disposal of sludge.

4.2.2 Each inspection parameter of each inspection category will be awarded a score. The scores to be quoted are listed below:

- 0 – Non-functional/Absent/Below Standard
- 1 – Unacceptable/Unsatisfactory
- 2 – Fully functional/Acceptable/Satisfactory

4.2.3 The score of all parameters in each category will be tallied and expressed as a percentage of the total number of points for that category. Subsequently, weighting factors will be applied to obtain the final grade (percentage) of the plants that will decide whether or not the facility will be awarded a license. Proposed weighting factors and the rationale for their magnitude are listed below:

Table 6: Weighting Factors

Inspection Category	% Rating	Rationale
Plant Equipment	20	Ensures proper plant operation
Water Quality Examination	60	Essential for protection of the environment and ensure that water discharged complies with legislation
Document Inspection	20	Useful to gain an idea of the maintenance and operation of the plant.

4.2.4 If the final percentage is above 90% (Class A), the plant will automatically be issued a license. If the final percentage is between 60 - 90% (Class B) management of the plant will be given a period to correct any problems. However, during this time the plant will still be allowed to operate but its operation will be closely monitored by the EPD. If a facility obtains a score less than 60% (Class C) the facility will not be licensed and it is suggested that a daily penalty be imposed until the operation of the plant is deemed satisfactory by the EPD.

4.3 Sample Grading

4.3.1 The tables below illustrate the steps necessary to determine the final class category, determining whether the company should be licensed or not. In order to determine this class, the parameters were assessed in a Boolean manner by assigning points of 0 (non-functional/absent/below standard) and 2 (fully functional/satisfactory). In other words, “S” would have been assigned 2 and “NF” would have been assigned 1 (S – satisfactory NF –

non-functional/absent/below standard). The calculation of the percentage for each of the three categories is outlined below:

4.3.2 Plant Equipment[7]

Name of Establishment	**sanitation** (A)	**colour coded/ labelling** (B)	**Total Points** (C)	**Fraction of Total Points** D=(A+B)/C	**Percentage** E = D x % for this category
Four Square Rum Distillery	S (2)	NF (0)	4	2/4	2/4 x 20% =10%

4.3.3 Water Quality Examination

Name of Establishment	**BOD** (F)	**COD** (G)	**TSS** (H)	**Total Points** (J)	**Fraction of Total Points** K=(F+G+H+I)/J	**Percentage** L = K x % for this category
Four Square Rum Distillery	S (2)	NF (0)	NF (0)	6	2/6	2/6 x 60% =20%

[7] Although general sanitation was not a parameter that was surveyed all of the facilities were found to have sanitary surroundings. It follows therefore that all treatment plants were assigned a value 2 or satisfactory for their sanitation.

4.3.4 Document Inspection

Name of Establishment	**maintenance records** (M)	**Records of sludge disposal** (N)	**Total Points** (O)	**Fraction of Total Points** (P)	**Percentage** Q = P x % for this category
Four Square Rum Distillery	S (2)	S (2)	4	4/4	4/4 x 20% =20 %

4.3.5 The class is subsequently determined by summation of the percentage accrue in each category.

Name of Establishment	**Plant Equipment** (E)	**Water Quality** Examination (L)	**Document Inspection** (Q)	**Final Percentage** E+L+Q	**Class Category for Licensing**
Four Square Rum Distillery	10%	20%	20%	50%	C

4.3.6 From this final percentage the class can be determined. In this case, the percentage falls within the range of 60 – 90 %, which is equivalent to Class B.

4.3.7 A complete list of the grades of all plants is located in Appendix E.

5 Conclusions

5.1 Conclusion

5.1.1 The 2005 Wastewater Monitoring Programme has highlighted a number of shortcomings of the programme which need to be addressed.

5.1.2 Firstly, many of the samples, both influent and effluent, are taken from sampling points, which might have contained material from previous days. This makes it difficult to comment on the present plant performance. Therefore, a mechanism needs to be established to ensure all treatment plants have appropriate sampling points. The samples should be taken from points that are flowing. Hence the EPD must make efforts to encourage operators to establish and maintain sampling locations from which flowing samples could be easily taken.

5.1.3 Finally, the plant grading exercise outlined in section 4 highlights two main points:

1. Grading of plants has the potential not only as a licensing tool but can also be used as a management tool. For example, the EPD could set a goal to increase the number of plant within Classes A & B from the current 48% to 60% in two years. Once this has been achieved a goal to have 85% of the plants within Class A and B in three years could be set. In this way, regulation of treatment plants by the EPD would be more goal-oriented.
2. However, the plant at the Four Square Rum Distillery was classed as C but the grading process did not take into account the fact that the effluent is shipped offshore and consequently poses no threat to the environs of Barbados. Hence the criteria

used as outlined above are too general and therefore need to be refined.

6 Recommendations

- EPD technical staff should be trained in the evaluation of wastewater systems.
- Each treatment plant should be fitted with sampling points prior to the holding tank.
- The grading process should be refined especially in the categories of plant equipment and document inspection.
- Operators should be required to keep records of sludge disposal frequency and to develop a manifest for their haulers to ensure appropriate disposal of their sludge.
- Single discharge limits for Enterococci and Faecal Coliform should be established so that if these limits are exceeded a more comprehensive assessment of the plant could be performed.
- A colour coding system should be established by the Barbados National Standards Institute for wastewater plants

Appendix A

Statistical Summaries and Removal Efficiencies for 2005

Effluent Statistical Summary 2005

Biological Oxygen Demand (BOD)

Average	44.32
Min.	0.30
Max.	275.00
St. Deviation	73.22

Chemical Oxygen Demand (COD)

Average	232.48
Min.	42.00
Max.	1569.00
St. Deviation	328.99

Total Kjelhal Nitrogen (TKN)

Average	21.88
Min.	2.00
Max.	75.00
St.Deviation	19.34

Dissolved Oxygen (DO)

Average	5.50
Min.	0.10
Max.	9.60
St. Deviation	2.93

Total Nitrogen (TN)

Average	36.00
Min.	24.00
Max.	48.00
St.Deviation	16.97

pH

Average	7.14
Min.	6.20
Max.	8.30
St. Deviation	0.51

Total Suspended Solids (TSS)

Average	118.80
Min.	2.00
Max.	1443.00
St. Deviation	285.83

Influent Statistical Summary 2005

Biological Oxygen Demand (BOD)

Average	147.04
Min.	13.00
Max.	580.00
St. Deviation	153.49

Chemical Oxygen Demand (COD)

Average	1365.37
Min.	50.00
Max.	7735.00
St. Deviation	2049.94

Total Kjelhal Nitrogen (TKN)

Average	104.69
Min.	2.70
Max.	664.00
St.Deviation	162.40

Dissolved Oxygen (DO)

Average	3.30
Min.	0.10
Max.	8.60
St. Deviation	2.72

Total Nitrogen (TN)

Average	21.90
Min.	1.80
Max.	42.00
St.Deviation	28.43

pH

Average	6.91
Min.	3.30
Max.	8.30
St. Deviation	0.83

Total Suspended Solids (TSS)

Average	1289.56
Min.	16.00
Max.	11840.00
St. Deviation	2768.96

Removal Efficiencies for 2005

Name of Establishment	BOD	COD	TSS	Total Phosphorous
Almond Beach Club	7.69%	32.00%	49.30%	21.22%
Almond Beach Village	98.62%	94.50%	89.74%	85.37%
Bachelor Hall	92.76%	96.15%	98.26%	90.70%
Bona Vista Home	93.04%	60.63%	94.87%	82.79%
Bridgetown Sewage Treatment	55.56%	22.10%	36.21%	36.57%
Coral Reef Club	99.60%	99.18%	99.98%	38.15%
Crystal Cove	58.57%	61.43%	-35.90%	26.18%
Discovery Bay Beach Hotel	-434.09%	45.65%	74.05%	-25.00%
Foursquare Rum Refinery	97.95%	43.72%	-256.25%	7.35%
Greensleeves	98.10%	97.98%	99.62%	86.02%
Hi Point Farm	91.20%	66.89%	5.56%	-38.54%
Inch Marlow	61.76%	28.57%	92.05%	43.91%
Kings Beach	96.32%	65.64%	25.64%	55.04%
Mullins	88.63%	95.01%	97.81%	75.25%
NCC Project Office/ESPU	97.33%	98.55%	99.54%	86.32%
Palm Rosa	99.19%	99.09%	99.65%	86.89%
Port St. Charles North Plant	-173.91%	55.49%	73.94%	15.66%
Port St. Charles South Plant	51.33%	-374.02%	-2,675.00%	-596.43%
Reeds House	95.70%	33.02%	5.26%	-105.56%

Sandy Lane	56.82%	54.51%	32.72%	-34.24%
Savannah Hotel	96.67%	87.12%	84.00%	43.23%
South Coast Sewerage Plant	-22.22%	27.42%	32.46%	
Tamarind Cove Hotel	-50.59%	28.53%	74.31%	33.48%
Turtle Nest	18.75%	-41.04%	-20.66%	-21.65%
Villa Nova	99.06%	97.17%	98.68%	84.57%

Bacteriological Statistical Summary 2005

Enterococci

Average	1.49E+05
Min.	2.00
Max.	2.20E+06
St.Deviation	4.51E+05

Faecal Coliform

Average	1.49E+06
Min.	0.00
Max.	1.30E+07
St. Deviation	3.42E+06

Appendix B

Statistical Analysis

Effluent Comparison of 2004 & 2005

Step 1: Hypothesis

H_0: The levels of pollutants in effluent during 2004 are greater than or equal to those of 2005

H_A: The levels of pollutants in effluent during 2004 are less than those of 2005

Level of significance: 5%

Step 2: Test for Normality

The BOD, COD, TKN, DO and TSS data for 2004 and 2005 were examined using the Kolmogorov-Smirnov test in addition to the Shapiro-Wilk test and it was found that the data were not normally distributed (See table below[1]).

Table 7

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	YEAR	Statistic	df	Sig.	Statistic	df	Sig.
BOD	2004	.422	18	.000	.340	18	.000
	2005	.274	25	.000	.647	25	.000
TKN	2004	.126	18	.200*	.940	18	.290
	2005	.237	25	.001	.865	25	.003
COD	2004	.317	18	.000	.628	18	.000
	2005	.281	25	.000	.608	25	.000
DO	2004	.113	18	.200*	.943	18	.323
	2005	.141	25	.200*	.898	25	.017
TSS	2004	.344	18	.000	.495	18	.000
	2005	.341	25	.000	.391	25	.000

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Consequently a non-parametric test had to be used to further analyse this data. Therefore the Mann-Whitney test was selected.

[1] Non-normality is indicated by the level of significance (Sig.) being less than 0.05.

Step 3: Application of the Mann-Whitney Test

The Mann-Whitney test was applied and the results in Tables 8 and 9 were obtained.

Table 8

Ranks

	Year	N	Mean Rank	Sum of Ranks
BOD	2004	21	24.74	519.50
	2005	25	22.46	561.50
	Total	46		
TKN	2004	21	23.40	491.50
	2005	25	23.58	589.50
	Total	46		
COD	2004	21	23.88	501.50
	2005	25	23.18	579.50
	Total	46		
DO	2004	18	19.86	357.50
	2005	25	23.54	588.50
	Total	43		
TSS	2004	21	21.81	458.00
	2005	25	24.92	623.00
	Total	46		

Table 9

Test Statistics[a]

	BOD	TKN	COD	DO	TSS
Mann-Whitney U	236.500	260.500	254.500	186.500	227.000
Wilcoxon W	561.500	491.500	579.500	357.500	458.000

a. Grouping Variable: Year

The values for BOD, TKN, COD, and TSS in Table 9 were compared to a critical value, $U_{critical}$ = 311 while DO value in Table 9 was compared to $U_{critical}$ = 267 and conclusions drawn.

Step 4: Conclusions

Since all the values in Table 9 (for the Mann- Whitney Test) are less then their corresponding critical U values it can be concluded that there is insufficient evidence at the 5% level to reject H_0. Therefore we conclude that the levels of pollutants in effluent during 2004 are greater than or equal to those of 2005.

Appendix C

List of Treatment Plants and Their Ages

Table 10: Ages of Treatment Plants in Barbados (U – unknown)

Name of Establishment	Age (years)
Foursquare Rum Refinery	9
Savannah Hotel	**U**
South Coast Sewerage Plant	7
Mullins Hotel	4
Mullins Restaurant	**U**
Kings Beach Hotel	2
Kings Beach Village	1
Bridgetown Sewage Treatment Plant	23
Crystal Cove	11
Tamarind Cove Hotel	11
Discovery Bay Beach Hotel	10
Coral Reef Club	1
Bachelor Hall	**U**
Greensleeves	**U**
Palm Rosa	**U**
Hi Point Farm	7
NCC Project Office/ESPU	**U**
Villa Nova	5
Reeds House	7
Almond Beach Village	8
Port St. Charles North Plant	**U**
Almond Beach Club	21
Bona Vista Home	4
Port St. Charles South Plant	5
Turtle Nest	**U**
Inch Marlow	1

Appendix D

Pollutant Standards and Sources

Table 11: List of Parameters and Their Standards

Parameter	***Standard***	***Source***
pH	6 – 9	MPCA
Total Phosphorous	1 mg ml	MPCA
Biochemical Oxygen Demand	30 mg/ml	MPCA
Chemical Oxygen Demand	100 mg/ml	NEPA
Total Nitrogen	5 mg/ml	MPCA
Total Suspended Solids	30 mg/ml	MPCA

MPCA – Marine Pollution Control Act (Discharge) Regulations –Proposed End of Pipe Discharge Standards

NEPA - National Environmental & Planning Agency (NEPA) in Jamaica

Appendix E

Classification of Treatment Plants[9]

[9] In spite of the fact that Savannah Hotel and Sandy Lane were not surveyed they are included in the classification based on their water quality results and the point awarded to all plants for satisfactory sanitation.

Table 12: List of Treatment Plants and Their Classification

Establishment Name	Final Percentage	Class Category
Almond Beach Club	70%	B
Almond Beach Village	80%	B
Bachelor Hall	90%	B
Bona Vista Home	90%	B
Bridgetown Sewage Treatment Plant	40%	C
Coral Reef Club	80%	B
Crystal Cove	50%	C
Discovery Bay Beach Hotel	10%	C
Foursquare Rum Refinery	50%	C
Greensleeves	90%	B
Hi Point Farm	50%	C
Inch Marlow	80%	B
Kings Beach Hotel	90%	B
Kings Beach Village	90%	B
Mullins Condominiums	30%	C
Mullins Restaurant	40%	C
NCC Project Office/ESPU	90%	B
Palm Rosa	90%	B
Port St. Charles North Plant	10%	C
Port St. Charles South Plant	10%	C
Reeds House	50%	C
Sandy Lane	10%	C
Savannah Hotel	70%	B
South Coast Sewerage Plant	40%	C
Tamarind Cove Hotel	10%	C
Turtle Nest	30%	C
Villa Nova	90%	B