Topic: Decentralised Wastewater Treatment Systems

Performance Assessment of Onsite Wastewater Treatment Systems in the Cayman Islands

C. Crabb
Department of Water Resources & Quality Control, Water Authority-Cayman, PO Box 1104, Grand Cayman, KY1-1102, Cayman Islands. (E-mail: Catherine.Crabb@waterauthority.ky)

ABSTRACT

A paper presented at the 2003 Annual Caribbean Water and Wastewater Association Conference: *"Onsite Wastewater: Here to Stay, How to Manage?"* discussed the Cayman Islands' development of an Onsite Wastewater Management Programme. This paper reviews the current Programme with emphasis on a performance assessment of onsite treatment systems.

Approximately 20% of wastewater generated in the Cayman Islands is collected and treated at the central wastewater treatment plant operated by the Water Authority; the remaining 80% is treated in onsite treatment systems comprised of approximately 13,500 septic tanks and 520 aerobic treatment units. All treated wastewater effluent is discharged to effluent disposal wells. Septic tanks serve the majority of developments constructed prior to 1990 as well as smaller developments constructed since that time. Aerobic treatment units are required at larger developments, as the systems are designed to achieve a higher level of treatment (secondary) than can be achieved by a septic tank alone (primary treatment).

In 2003 a basic performance assessment was carried out which found that 20% of installed onsite aerobic treatment units were inoperable. In April 2008 a quantitative assessment of onsite treatment systems was initiated. This paper discusses results from 200 aerobic treatment units and 50 septic tanks which were sampled and analysed for five-day Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids (TSS). Overall, only thirteen per cent of the systems sampled met the Cayman Islands' effluent limit of 30 mg/L for both BOD_5 and TSS. The results of the assessment are further analysed by technology type, operational status, capacity of system, age of system, and type of development served.

The performance assessment of onsite treatment systems, which is ongoing, provides the empirical data necessary to advance the Cayman Islands' Onsite Wastewater Management Programme.

1.0 INTRODUCTION

Management of onsite wastewater treatment remains a challenge in many areas including the Cayman Islands. For years onsite treatment systems were seen as temporary installations to be replaced by a central system. As a result, onsite systems were subject to limited oversight by regulatory agencies. The pace and pattern of development and challenges to extending central sewerage systems has resulted in many areas being served by onsite treatment systems for the long term. Recognition that onsite treatment will continue to be part of a region's overall wastewater management scheme has increased efforts to optimise management and performance of onsite systems (USEPA 1997). The Caribbean region, where less than 20% of the population is served by central systems, is also focusing on the issue through the Land Based Sources Protocol of the Cartagena Convention (Healy 2002). This paper discusses the evolution of the management of on-site wastewater treatment in the Cayman Islands since the Water Authority took on the task in 1990. The discussion emphasises results of a quantitative assessment of the performance of onsite systems and how the results will be used to improve the Authority's approach to the management of onsite wastewater treatment.

1.1 Onsite Wastewater Treatment in the Cayman Islands

The Water Authority of the Cayman Islands was established with the passing of the Water Authority Law in 1982. The Authority's duties include ensuring potable water supply, providing for the collection, treatment and disposal of sewage where a general sewerage scheme is rational, regulating the collection, treatment and disposal of wastewater in all areas, and protecting water resources in general. The Authority installed a centralised sewerage system in the main tourist area of Seven Mile Beach in the late 1980's; areas outside the centralised system's collection area continue to rely on onsite treatment. As the population and wastewater generation have increased at a rapid rate, the relative proportions treated via the central system versus onsite systems have remained fairly consistent, at 20% and 80%, respectively. Refer to table 1 for details.

Table 1: Status of Onsite Wastewater Treatment in the Cayman Islands 2003 - 2009

	Population (Number)	Volume Treated in Central System (USGPD)	Volume Treated in Onsite Systems (USGPD)	Treated in Onsite Systems (Percent)
2003	43,000	1,000,000	4,100,000	80%
2009	59,000	1,300,000	5,800,000	82%
% increase	37%	30%	41%	2%

Information in table compiled from: Cayman Islands Economics and Statistics Office (CIESO), 2008; Cayman Islands Lands & Survey (CIL&S), 2009; Kairi Consultants Ltd., 2008; Water Authority-Cayman (WAC), 2009.

1.2 Onsite Wastewater Management in the Cayman Islands

In 1990 the Water Authority assumed responsibility from the Department of Environmental Health for oversight of onsite treatment in addition to the centralised sewerage system. The Onsite Wastewater Management Programme has evolved since its inception. The Authority's initial approach, where approval of systems was limited to initial design-based requirements and not subject to performance testing after installation, was similar to that of many regions (USEPA 2002). In 2003, the Authority's programme was restructured using the United States Environmental Protection Agency's Voluntary Guidelines for Management of Onsite Wastewater Treatment Systems (USEPA 2002). The EPA Guidelines provide a framework of management elements designed to allow the management approach to move along a continuum from basic to intermediate to advanced, as a community's needs and resources change. The Authority began with a basic approach and a commitment to progress along the continuum. Table 2 outlines the Authority's initial and current approach.

Table 2: Approach to Elements of Onsite Wastewater Management Programme

ELEMENT	INITIAL APPROACH	CURRENT APPROACH
Inventory	Basic: Maintain listing of systems in Excel format.	Advanced: Implementation of a web-based database to track inventory, maintenance and enforcement.
Onsite System Requirements	Basic: Specify requirements (septic tank or aerobic treatment unit) depending on size of development.	Basic +: Specify that aerobic treatment units must be certified package plants. Require system approval for building permit.
Education	Basic: Provide information on ad hoc basis in field and at meetings. Provide brochures regarding care and use of onsite systems.	Intermediate: Disseminate information via the Water Authority's website: **www.waterauthority.ky** Communicate with all stakeholders in a comprehensive and consistent manner.
Monitoring	Capability for quantitative analysis	
	Basic: Limited capability for BOD & TSS analysis.	Advanced: Water Authority Laboratory accredited for analyses including BOD_5 & TSS.
	Inspections	
	Basic: Inspect new installations and existing systems on complaint basis.	Intermediate: Inspect and sample existing systems as well as new installations and complaint-based inspections.
	Staffing	
	Basic Staff of one.	Intermediate: Second position in 2006, Part-time position in 2009, Third full-time position budgeted.
Enforcement	Basic: Complaint-based actions.	Basic: Complaint-based and notice that enforcement will follow subsequent effluent sampling.

In 2003, a basic evaluation of installed aerobic treatment systems was conducted in Cayman based on observations made during site surveys including operation of mechanical equipment, general appearance and odour. Twenty percent of the systems surveyed were found inoperable and many others appeared neglected (Crabb 2003). The results clearly indicated the need for a quantitative performance assessment to determine the extent and pattern of poorly performing systems. In November 2005 the Water Authority Laboratory received accreditation from the American Association for Laboratory Accreditation (A2LA) for the analysis of Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids (TSS), the parameters for effluent standards under Water Authority Law. The accreditation provides a high level of confidence in analytical results, allowing performance testing to move forward.

In April 2008, the Authority initiated an effluent monitoring programme with emphasis on Aerobic Treatment Units or ATUs, with a smaller, but representative, sampling of septic tanks. Results of the assessment clearly indicate the need for improvement in both the performance and management of onsite treatment systems. Analysis of the results provides insights that will guide the advancement of both.

2.0 METHODS

The onsite wastewater effluent monitoring programme is carried out by the Authority's Development Control and Quality Control Departments. Development Control is responsible for the field work and work with the stakeholders while Quality Control is responsible for analytical work and quality control per A2LA standards. Sampling is conducted one day per week, seven samples per event. Sample sites are selected to ensure representation from different types of treatment systems and developments. Due to logistics, sampling is limited to Grand Cayman; however, the results can be generalised for the Sister Islands of Cayman Brac and Little Cayman, whose combined population is less than 5% of the total population of the Cayman Islands.

Onsite treatment systems in the Cayman Islands are comprised of approximately 13,500 septic tanks and 520 aerobic treatment units (ATUs). Septic tanks provide primary treatment; i.e., they are designed to remove settleable solids, while ATUs are designed to provide secondary treatment where dissolved organic matter is also removed. ATUs refer to a broad category of pre-engineered onsite treatment systems which can be further categorised by design variations of the process: containment of wastewater, introduction of oxygen, suspension of biomass in wastewater and separation of biomass from treated effluent. Table 3 describes the types of onsite systems and their utilisation in the Cayman Islands.

Table 3: Onsite Treatment System Types, Descriptions, and Utilisation of Each

SYSTEM TYPE	**DESCRIPTION**	**Number of Installations**	**Percent by Volume of Flow**
PRIMARY TREATMENT			
Septic Tank **(ST)**	A watertight, two-compartment concrete or poly settling tank discharging directly to an effluent disposal well.	13,500	71%
SECONDARY TREATMENT			
Suspended Growth **(SG)**	Activated sludge systems utilising aerators to oxygenate and mix the contents, keeping microorganisms and sewage in contact.	251	9%
Hybrid **(HYB)**	Activated sludge systems that utilise both suspended and attached microorganism growth by introducing a medium with high surface area within the aerated chamber.	163	8%
Sequencing Batch Reactor **(SBR)**	Activated sludge suspended growth systems in which all major steps: settle, mix and aerate, settle and decant, occur in the same tank in sequential order.	52	8%
Rotating Biological Contactor **(RBC)**	Attached growth systems utilising disks of plastic medium mounted on a horizontal shaft that rotates, alternatively exposing the media disks with their attached biomass to air and wastewater.	53	4%
Membrane BioReactor **(MBR)**	Activated sludge suspended growth system that utilises membranes for final solid / liquid separation in place of a clarifier.	1	< 1%

Information in table compiled from CIL&S, 2009; Kairi Consultants Ltd., 2008; WAC, 2009.

The sampling point for each system is selected to ensure it represents “end of pipe” effluent quality being discharged to the effluent disposal well. Depending on the design of the system and access to it, samples are taken from the final clarifier, below the water surface and next to the outlet, utilising a Wheaton subsurface grab sampler, or taken directly from the effluent disposal well, utilising a stainless sample cup to intercept the flow as it discharges to the well. Samples are collected in 1 litre polyethylene bottles labelled with date and time of collection, technician’s initials and analysis required. This information is logged in the field book along with notes on the treatment system’s access, operation and appearance. Samples are transported to the laboratory in ice chests.

In the laboratory, samples are analysed for electrical conductivity (EC) using a YSI85 meter, pH per Standard Method 4500H^+B, chlorine per Standard Method 4500Cl G**,** Biochemical Oxygen Demand (BOD_5) per Standard Method 5210B and Total Suspended Solids (TSS) per Standard Method 2540D.

3.0 RESULTS AND DISCUSSION

3.1 Performance Measures

Effluent quality results from 250 onsite systems are compared to 30 mg/L effluent limits for BOD_5 and TSS. The 30 mg/L BOD and TSS limits are widely used as the standard for secondary treatment (U.S. CFR, NSF/ANSI) and have been adopted by many regulatory agencies (Healy 2002) including the Water Authority-Cayman, with some exemptions. Water Authority Law (1996) stipulates that the limits apply to all domestic effluents discharging from any sanitary works unless the Authority exempts a temporary facility from compliance based on a determination that achievement thereof would place an unreasonable burden on the operator of the facility, and in all cases in which it is likely that the public sewerage facilities will be provided within a reasonable time. The Water Authority exempts developments constructed prior to 1985 when the Regulations were first promulgated and newer developments considered small (those located on a parcel where less than 1,800 US gallons per day of wastewater is generated) from meeting the “30/30” effluent limits.

Table 4 provides a general reference for effluent quality of residential wastewater before and after treatment. The data are typical for residential dwellings equipped with standard water-using fixtures and appliances.

Table 4: Representative Concentrations in Residential Wastewater

Parameter	Untreated (mg/L)	Treated in Septic Tank (mg/L)	Treated in ATU (mg/L)
BOD_5	155 - 286	140 - 200	5 - 50
TSS	150 - 330	50 - 100	5 - 100

Source: United States Environmental Protection Agency (USEPA), 2002, *Onsite Wastewater Treatment Systems Manual*.

Effluent results are also compared based on factors that may affect performance including: type of system, operational status of system, age of system, capacity of system, and type of development served.

3.2 Overall Results

Overall, only thirteen percent of the systems sampled met the limits for both BOD and TSS (Figure 1). The results ranged widely (Figure 2), often not only exceeding the "30/30" limits, but exceeding the industry standard for *untreated* domestic wastewater (Figure 3).

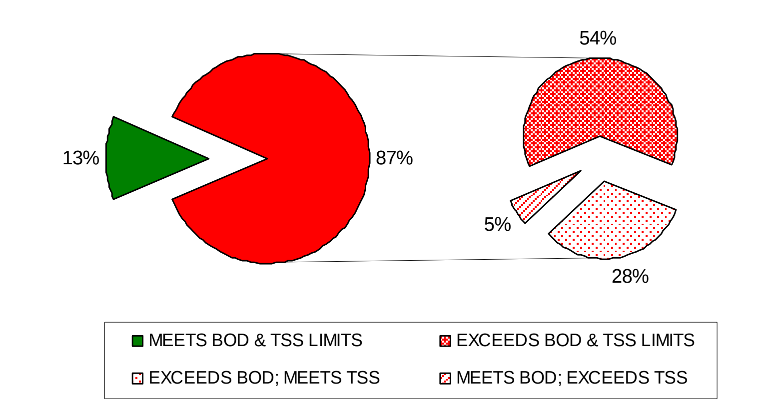


Figure 1:Compliance with "30/30" LIMITS

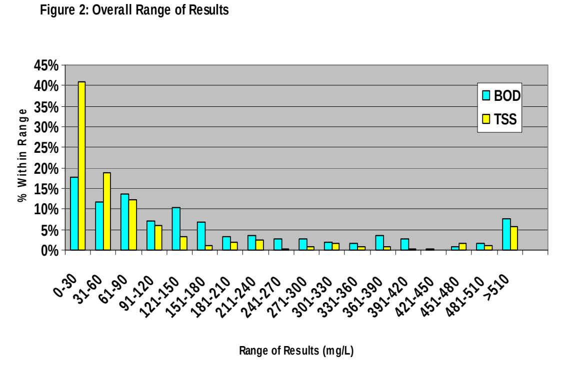


Figure 2: Overall Range of Results

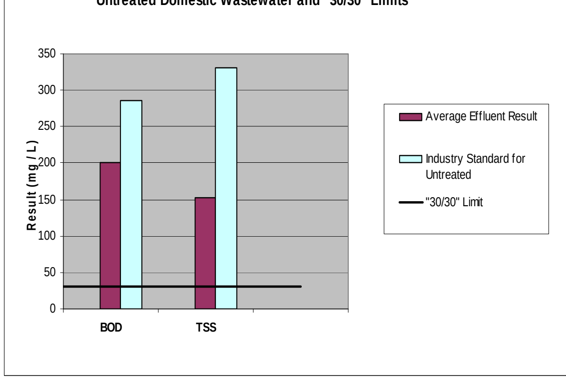


Figure 3: Results Relative to Industry Standard for Untreated Domestic Wastewater and "30/30" Limits

Based on observations of the conditions of systems sampled, a likely explanation for results that exceed concentrations expected in untreated wastewater is excessive solids build up in the system resulting in reduced hydraulic capacity, reduced residence time for treatment and increased wash out of concentrated solids.

3.3 Results by Treatment Type

Results were analysed by type of treatment system to determine whether certain types performed better than others; reference Table 3 for description of treatment types. Average results for all types, with the exception of the single MBR (membrane bio-reactor) system operating on the Island, exceed the "30/30" limits. Both Figures 4 and 5 indicate that all types of ATUs (SG, HYB, RBC, SBR, MBR) produce better effluent results than septic tanks (ST).

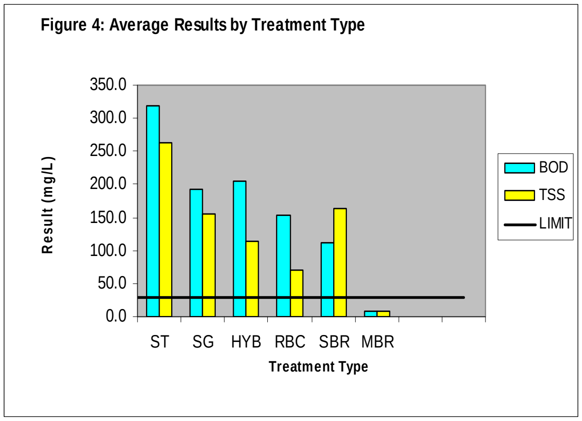
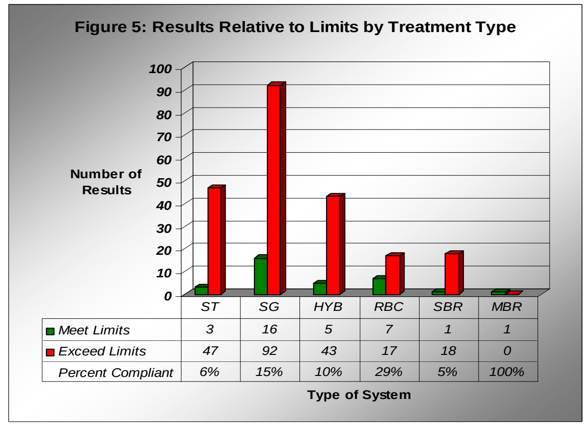


Figure 4: Average Results by Treatment Type



	ST	SG	HYB	RBC	SBR	MBR
Meet Limits	3	16	5	7	1	1
Exceed Limits	47	92	43	17	18	0
Percent Compliant	6%	15%	10%	29%	5%	100%

Figure 5: Results Relative to Limits by Treatment Type

As ATUs are designed to achieve a higher level of treatment (secondary) compared to septic tanks (primary), these results are to be expected. The exceptional results for the MBR (membrane bio-reactor) system show the results achievable when microfiltration is used for final solid / liquid separation in place of a clarifier. These results are even more impressive given that the system serves a brewery which was in chronic non-compliance before investing in a system designed to treat its high-strength flows.

3.4 Results by Operational Status

For all systems sampled, notes were logged indicating whether mechanical equipment was operating and describing general conditions. For analysis, operational status was categorised as *"passive",* for septic tanks, *"operational"* for ATUs with operating mechanical equipment and *"non-operational"* for ATUs with non-operating mechanical equipment. The results clearly show that operational ATUs achieve the best average effluent results (Figure 6) and have the highest rate of compliance with "30/30" BOD and TSS limits. The results also show that non-operational ATUs function no better than septic tanks (Figures 6 and 7).

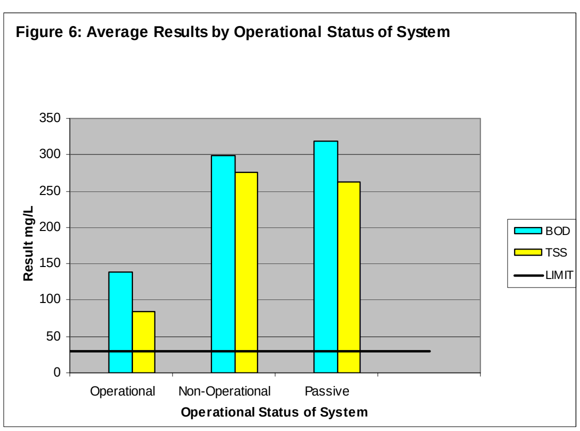
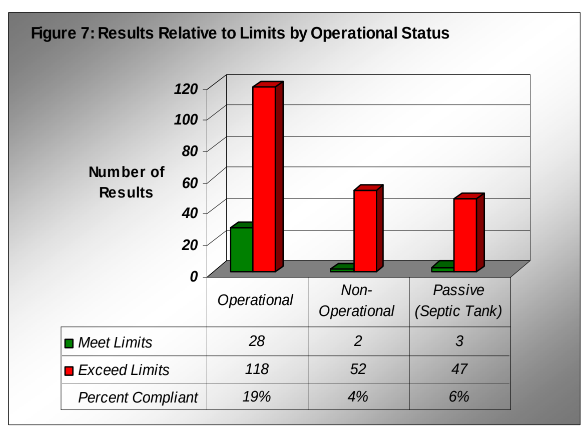


Figure 6: Average Results by Operational Status of System



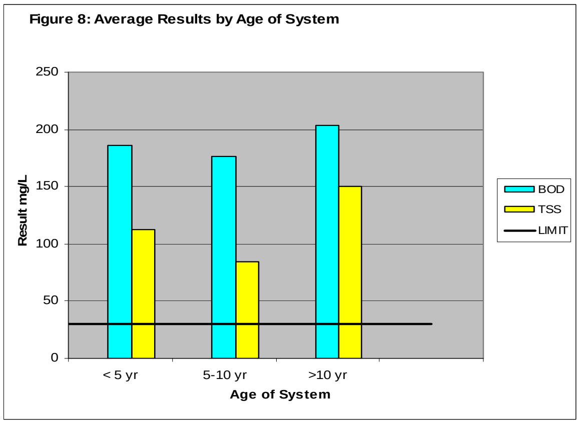
	Operational	Non-Operational	Passive (Septic Tank)
Meet Limits	28	2	3
Exceed Limits	118	52	47
Percent Compliant	19%	4%	6%

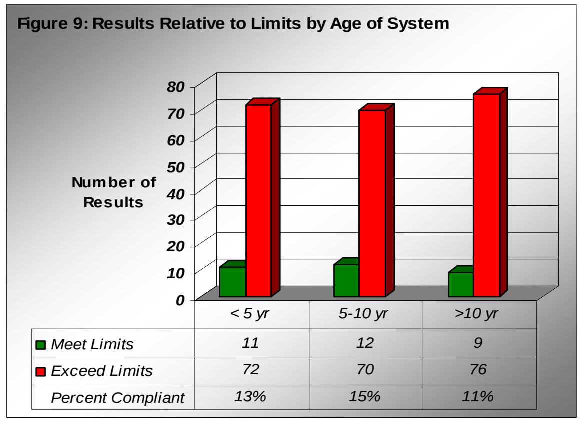
Figure 7: Results Relative to Limits by Operational Status

It is not surprising that non-operational ATUs function much like septic tanks, as the mechanisms for secondary treatment; i.e., mixing and aeration, are not working.

3.5 Results by Age of System

Results were analysed by age of installation to determine whether a system's efficiency was a function of the age of the system. Age categories are for installations less than five years old, five to ten years old and more than ten years old. Most ATUs have a design life of twenty to twenty five years; however, there are few, if any, ATU installations in Cayman that have been in operation that long.

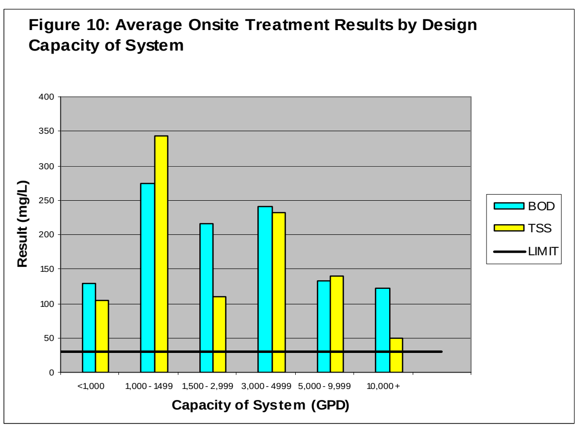


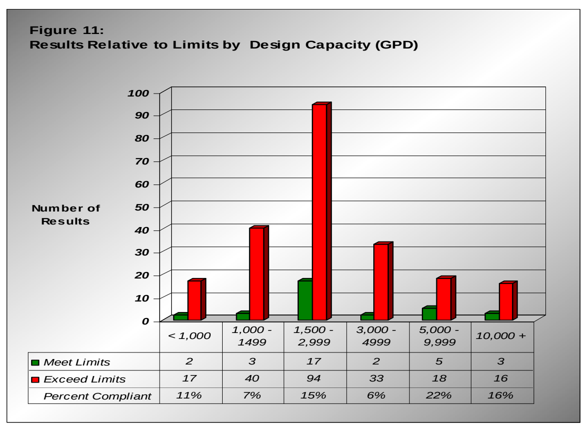


Results show little variability attributed to the age of the systems (Figures 8 and 9). While the average results do increase some after ten years (Figure 8), the percentages of systems meeting limits (compliant) in the age ranges do not decrease with age (Figure 9). The results therefore indicate that performance does not necessarily decline over time. A follow up assessment will be required to determine whether systems can perform beyond their design life.

3.6 Results by Capacity of System

Results were analysed by design capacity to discern whether certain ranges performed better or worse overall. Figure 10 shows the worst average results for systems with design capacities in the 1,000 – 1,499 gallons per day (gpd) and 3,000 – 4,999 gpd categories. Figure 11 supports this finding, showing that the worst level of compliance occurs for systems in those same categories.





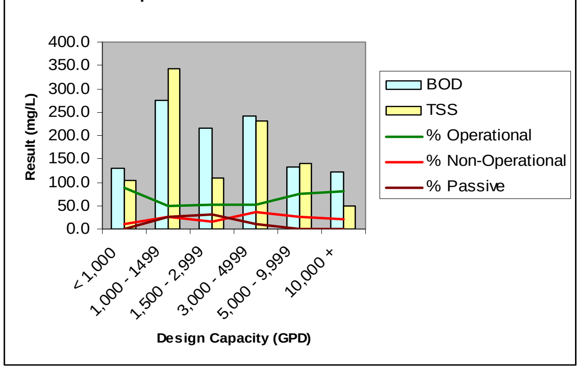


Figure 12: Average Results by System Design Capacity, Relative to Operational Status

To determine whether there was a correlation between average results by design capacity and a particular system type, operational status, age, or type of development served, each of those factors were graphed for the capacity ranges. The only correlation found was with operational status of systems. The capacity ranges with the worst (highest) average results also had the highest ratio of non-operational to operational systems (Figure 12).

3.7 Results by Type of Development Served

Results were analysed by type of development served to discern variances in results that may be attributed to the different character (strength, volume and rate) of wastewater likely to be generated. Standard onsite treatment systems are designed to treat residential wastewater; therefore, performance may be affected if the character of wastewater is appreciably different than that of residential wastewater.

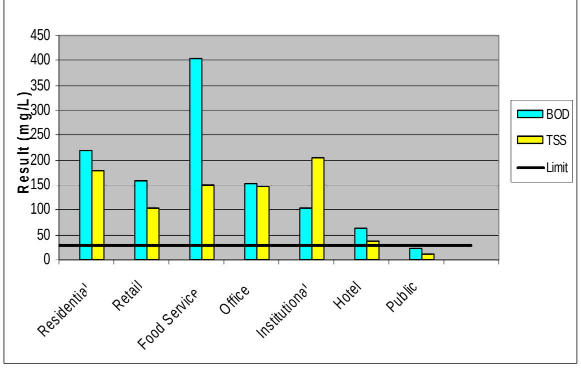


Figure 13: Average Results by Type of Facility Served

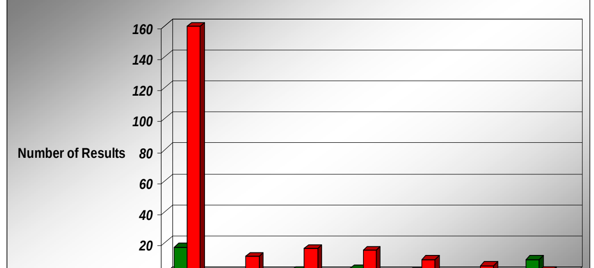


Figure 14: Results Relative to Type of Facility Served

	Resident	Retail	Food Svc	Office	Institution	Hotel	Public
Meet Limits	17	0	2	3	1	0	9
Exceed Limits	160	11	16	15	9	5	2
Percent Compliant	10%	0%	11%	17%	10%	0%	82%

Figures 13 and 14 show the best average results and a compliance rate of 84% for public facilities; however, this result may be misleading due to the character of wastewater generated. Public facilities are those used on a periodic basis; e.g., churches, park facilities and restroom facilities for cruise-ship passengers. Wastewater generated at these facilities is limited to that from restrooms receiving heavy use for relatively short and infrequent periods. Data on influent strength and daily metered flows would be needed to determine whether a combination of low strength waste and slug loading (surge flows) may account for the results shown. Results shown in Figures 13 and 14 for hotels show a relatively good average result, yet none of the 5 facilities met effluent limits. This may be attributed to the small sample size for this sector. Results for food service facilities show inordinately high BOD levels (Figure 13). This is likely attributed to facilities with poor maintenance of grease interceptors which are designed to remove grease and food particles that can organically overload treatment systems. Results for institutional facilities which include hospitals, schools and the prison, stand out for their low ratio of BOD to TSS; however, it was determined that the results from an animal hospital's septic tank (BOD 300 mg/L; TSS 1800 mg/L) skewed the results for this sector. Average results for retail and office facilities indicate their wastewater character is similar to that of residential wastewater; however, none of the retail facilities sampled met effluent limits. This may reflect the difficulty in properly sizing onsite systems for retail centres which are frequently proposed as low-water use; i.e., only equipped with restroom facilities for employees and customers. Over time, and without always being subject to review, changes of use occur that can overwhelm the treatment capacity of the installed system.

4.0 CONCLUSION

A 2003 paper: *"Onsite Wastewater: Here to Stay, How to Manage?"* (Crabb 2003) indicated poor performance of onsite treatment systems in the Cayman Islands, based on qualitative factors; e.g., appearance, odour. The performance assessment of onsite treatment systems discussed in this paper quantifies the extent of the problem of poor performance: only 13% of systems meet the "30/30" limits for BOD and TSS, and 20% of systems were found to be discharging effluent that exceeds standard levels for *untreated* wastewater. When looking at performance of onsite treatment systems relative to factors that may affect performance, results indicate that all variations of Aerobic Treatment Units (ATUs), when operational, outperform septic tanks while inoperable ATUs perform the same as septic tanks. Results indicate little variation in performance of onsite systems as a function of the age of the installation. As few ATUs were installed more than twenty years ago in the Cayman Islands, it remains to be seen how they perform beyond their design age of twenty to twenty five years. Results did indicate poorer performance within two design capacity ranges analysed; however, further analysis indicated that this was attributable to the operational status of systems sampled within those ranges. Results indicate that systems serving food service are the most likely to have performance affected by organic overloading while systems serving public facilities are the most likely to have performance affected by slug loading (surge flows).

The results of the assessment are useful in providing specific data on the performance of individual systems and on a larger scale, aggregate analysis of the results provides guidance to advance the performance and management of onsite wastewater treatment systems in the Cayman Islands. The findings of the assessment are already being incorporated into each element of the Onsite Wastewater Management Programme outlined in Table 2:

<u>Inventory:</u> A web-based wastewater management database to better track information on installation, operation, maintenance, sampling and enforcement is currently being implemented.
<u>Requirements</u>: Results indicate the need to strengthen requirements relating to system access, routine maintenance including periodic removal of solids, flow equalisation where indicated, and review of all proposed changes of use.

Education: Stakeholder awareness has increased markedly through notification of owners and service providers regarding effluent sampling results, the objectives of the Onsite Wastewater Management Programme, and the responsibilities of each stakeholder (the Water Authority, system installers, owners and service providers). Subsequent press coverage has further increased awareness and support for the programme. Service providers are being encouraged to avail themselves to a correspondence course offered through California State University Sacramento's Office of Water Programs which leads to certification in *Small Wastewater System Operation and Maintenance* (2003). Water Authority staff involved in the Programme have obtained, or are studying for, the certification which is likely become a requirement for service providers.
Monitoring: The effluent monitoring program is ongoing with the near-term goal of sampling the remaining third of installed ATUs while re-sampling systems that have been serviced to address deficiencies highlighted by an initial test. The "before and after" results will provide valuable information on the level of service being provided and evidence of the benefits of routine service. The longer-term goal is to increase capacity for analysis to allow for more frequent routine sampling of systems. It is essential that this be done in accordance with A2LA standards, as the reliability of the analytical results provided by the Water Authority Laboratory has proven to be invaluable.
Enforcement: Notifications of results sent to ATU owners included a warning to those with results exceeding "30/30" limits that necessary service and repair must be completed. In the event that subsequent sampling results exceed limits, enforcement will proceed per Water Authority Law (1996). In cases that pose an immediate risk to public health; e.g., discharge to the surface, enforcement actions are initiated without delay.

With the vast majority of wastewater in the Cayman Islands being treated onsite and the challenges in extending the central system, onsite treatment will continue to be part of the Cayman Islands' overall wastewater management scheme. The optimisation of existing systems will have a significant overall impact and will allow for consideration and application of alternative methods of effluent disposal that can provide a higher level of treatment and beneficial reuse such as irrigation or groundwater recharge.

5.0 ACKNOWLEDGMENTS

Special thanks to those carrying out the field work and laboratory analysis for their critical contributions. Their careful and consistent work and documentation of the same, under less than pleasant conditions, ensures the credibility of the work. Thanks to other colleagues for their valuable insights, feedback and general support of the project and programme.

6.0 REFERENCES

American Association for Laboratory Accreditation (A2LA), Environmental Program [Online] http://www.a2la.org/appsweb/environmental.cfm [2 June 2009].

California State University 2003, *Small Wastewater System Operation and Maintenance Volumes I & 2*, Field Study Training Program, California State University Sacramento Office of Water Programs.

Cayman Islands Economics and Statistics Office 2008, *Population Features in Cayman Islands,* [Online] http://www.eso.ky/pages1.php?page=populationandvitalstatistics [11 May 2009].

Cayman Islands Lands & Survey Data 2009, Features data for Geographic Information Systems [Online, by subscription] http://www.caymanlandinfo.ky [12 May 2009].

Crabb, C. 2003, 'Onsite Wastewater: Here to Stay, How to Manage?', in proceedings of the 12th Annual Caribbean Water and Wastewater Association Conference, Bahamas.

Kairi Consultants Ltd. 2008, *Cayman Islands National Assessment of Living Conditions 2006-07*, [Online] http://www.caribank.org/titanweb/cdb/webcms.nsf/0/F96AEA1C5B79F4F60425750E006D6F26/$File/CPACayman-Vol1Main.pdf [12 May 2009].

National Sanitation Foundation / American National Standards Institute, Standard 40 [Online] http://www.nsf.org/business/wastewater_certification/standards.asp?program=WastewaterCer#std40 [15 June 2009].

Sealy, H. 2002, 'The Land Based Sources of Marine Pollution – Implementation Challenges', paper presented at the United Nations Environment Programme Caribbean Environment Programme Regional Training Workshop, Port of Spain Trinidad, 9-13 December 2002.

United States Code of Federal Regulation December 2005, 40 CFR 133.102(c).

United States Environmental Protection Agency 2002, *Onsite Wastewater Treatment Systems Manual,* EPA/625/R-00/008.

United States Environmental Protection Agency 1997, 'Response to Congress on Use of Decentralized Wastewater Treatment Systems', EPA 832-R-97-001b.

United States Environmental Protection Agency 2002, *Voluntary Guidelines for Management of Onsite Wastewater Treatment Systems,* EPA 832-B-03-001.

Water Authority-Cayman 2009, metered wastewater flow data, onsite treatment system inventory records, Grand Cayman, Cayman Islands.

Water Authority Law (18 of 1982), 1996 Revision.

Water Authority Regulations, 1999 Revision.