INSTITUTE OF APPLIED SCIENCES

THE UNIVERSITY OF THE SOUTH PACIFIC

A REVIEW OF THE STANDARD OF WASTEWATER TREATMENT IN FIJI'S TOURISM INDUSTRY

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By

Institute of Applied Sciences
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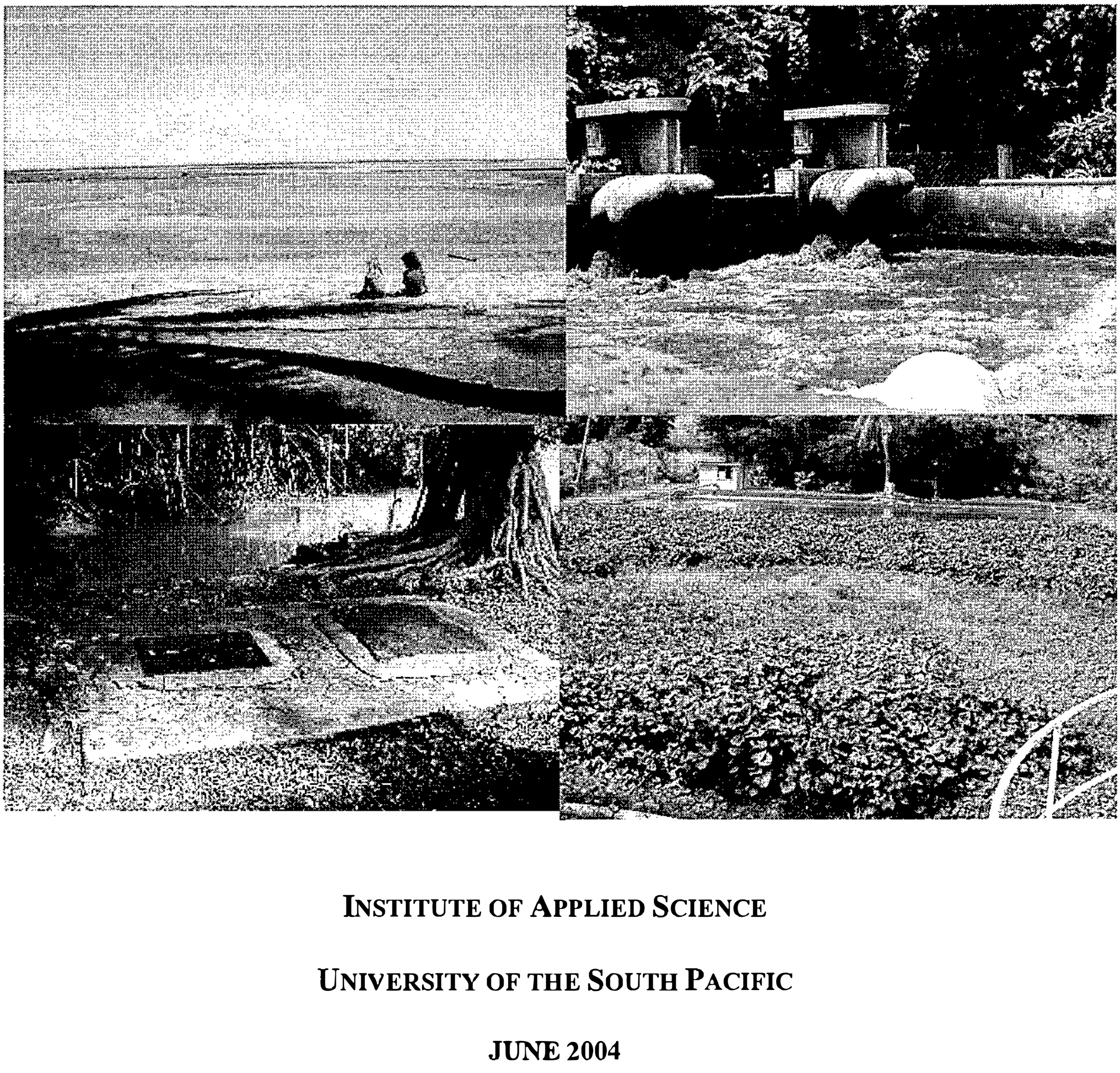

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Executive Summary

A JICA sponsored study has found the standard of wastewater treatment of Fiji's resorts is poor. An analysis by the Institute of Applied Science (University of the South Pacific) of 18 resorts wastewater effluent was compared to a variety of international standards. None of the resorts discharged effluent which met all the standards and many of the resorts did not meet even half the standards. The growing problem of extreme seaweed growth around some island resorts and coastal areas and findings of high nutrient levels in coastal waters, both indicate that resort wastewater effluent pose a serious problem to the coastal environment. This will undermine the resource that tourists are coming to see, as well as the subsistence livelihood for many coastal villages.

The study consisted of a questionnaire, inspection visits to 21 resorts, and chemical analysis of wastewater. Key findings from the questionnaire were:

- About 1/3 of resorts reuse their greywater (shower, sink water) for irrigation.
- About 40% of resorts use some form of low or non-phosphate detergents.
- About 40% of resorts had some form of on-site treatment plant, 40% have septic tanks, and 26% pump their waste to municipal treatment plants.
- About 50% of resorts had primary treatment, which includes septic tanks, and 23% secondary treatment.
- About half of the resorts that had treatment plants reused their treated effluent for irrigation.
- Four resorts directly discharge partially-treated sewage effluent direct to the ocean or creeks leading to the ocean.
- 7) A quarter of resorts bury their sludge from the treatment plant processes on site.
- 8) 36% of resorts have upgraded their treatment systems in the last 7 years with around one third of resorts planning more upgrades.

The results from the effluent analyses showed a great variation in the levels of many parameters, with resorts with ponds/wetlands at the final treatment stage producing the best quality effluent. The average results were (mean ± standard deviation): Temperature 31±1°C, pH 7.7±1.3, Dissolved oxygen 2.3±3.7 mg/L, Biochemical oxygen demand 653±1905 mg/L, Total suspended solids 307±854 mg/L, Total nitrogen 56±50 mg/L, Organic nitrogen 30±45 mg/L, Ammonia 37±36 mg/L, Nitrate and nitrite 2.0±5.4 mg/L, Total phosphorus 11 ±10 mg/L, Dissolved phosphate 4.7±3.2 mg/L, Faecal coliforms 1.4 million±2.9 million/100mL.

For direct effluent discharges to the sea and septic tanks located near the ocean, the overall treatment standard is insufficient to protect coral reefs from harm and not pose a health risk to swimmers. Many resorts discharge large amounts of treated effluent to land, particularly for irrigation of golf courses and gardens. The porous coral sand/rock soils common at most sites would not remove much of the nutrient loading in the long-term and it is unknown how much any vegetation present is capable of uptaking. Observations of algal growth around many resorts suggest that leaching of nutrients to the sea is occurring.

The major recommendations of the study are:

1) Resorts in Fiji should upgrade to an acceptable standard of wastewater treatment (e.g secondary treatment with further nutrient removal systems such as wetlands) especially for resorts near coral reef areas.
2) All resorts should adopt the use of low- or non-phosphate detergents as they are an easy way to markedly reduce the P content in sewage and laundry wastes
3) Resorts should conduct regular monitoring of key waste parameters such as nutrient, faecal coliform and BOD levels to judge the effectiveness of their treatment systems.
4) Ministry of Health should adopt appropriate standards for effluent discharges and require resorts to comply. In addition, no direct discharge of effluent to the marine environment should be allowed unless it meets a suitable standard and no other alternative method of discharge exists.

Objectives of the Study

The objective of the study was to provide an independent review of the current state of wastewater treatment practices in the Fijian tourism industry. This study will provide both the regulatory authorities and the tourism industry with a benchmark, based on real data, so that strategies can be drawn up for improvements which will serve the industry and people sharing the use of coral reef areas. The study was conducted by the Institute of Applied Sciences with funding provided by the Japanese International Cooperation Agency (JICA).

Background

The Fiji Islands are surrounded by numerous fringing coral reefs which are an extremely important natural resource, valuable as local fishery areas, tourist attractions, and for protection of the coastline from the damaging effects of waves. Over the last 20 years, there has been increased development on the coastline in Fiji for tourism. The tourism industry is very important to Fiji's economy, currently accommodating over 440,000 visitors and generating over FJ$630 million in revenue per year (Fiji Bureau of Statistics 2003 data). Many new resorts are currently being developed and it is predicted that visitor numbers will increase. Most tourist hotels and resorts are situated on the coastline of Fiji to enable utilization of the coral reef and lagoon environments for activities such as swimming, snorkeling, scuba diving, surfing, and fishing.

Coral reefs are very sensitive to changes in their environmental conditions, and increased levels of freshwater, sediment, and pollutants can readily stress or kill them (Birkeland 1997). Fiji's reefs are typically very close (0-400m) to the shoreline, with limited flushing to the open ocean and are therefore very susceptible to damage from land-based pollution. High levels of algal growth have been observed on many reef areas in Fiji (Coral Cay 2001) which is a symptom of increased nutrient levels and overfishing of herbivore grazer species (Goreau & Thacker 1994; McCook 1999; Szmant 2002). Several other locations around the world (Hawaii, Caribbean, Belize) have experienced similar algal problems. Extensive growth of algae results in competition for space between the algae, coral and other organisms leading to the overgrowth and smothering of coral and prevents fish and other reef inhabitants from finding food and shelter. There may also be a shading effect caused by the algae which would decrease the amount of light reaching the coral making it unable to photosynthesize effectively.

An assessment of nutrient (nitrate and phosphate) levels along the near shore water of the Coral Coast (Mosley & Aalbersberg 2003) and the Mamanuca Island group (unpublished data) showed that average values are nearly double the levels in the unpolluted Astrolabe Lagoon (Morrison et al. 1992) and above water quality guidelines for coral reef areas (ANZECC 2000). Nutrient levels tend to be especially high in front of resorts and settlement areas along the Coral Coast. Surveys by Greenpeace in the Mamanuca Islands in 1997 also indicated widespread growth of algae and although nutrient levels were low, the presence of faecal coliforms indicated sewage discharge. Faecal coliform levels were particularly high, in some cases exceeding recreational exposure standards, near point sources of sewage discharge such as near tourist resorts (Greenpeace 1997).

Sewage effluent is thought to be the main source of the pollution of the nearshore waters around resorts in Fiji. Effluent normally contains high levels of nutrients, suspended matter and occasionally pathogens. Proper sewage waste disposal is a difficult challenge for resorts in Fiji, particularly on small islands, but also on the larger main islands where the public reticulated sewage system does not extend to many areas. Most resorts carry out some form of on-site wastewater treatment. A survey by Greenpeace (1997) found that the majority (66%) of resorts were only carrying out primary treatment of their effluent (i.e basic separation of solids from liquids. e.g. settling ponds and septic tanks). This is somewhat concerning as secondary treatment (i.e removal of dissolved organic matter and fine suspended solids) is the accepted minimum level of effluent treatment in many countries around the world (e.g. New Zealand, Australia, United States). Prior to this study there has not been a study in Fiji which involved the sampling of wastewater from the resorts and comparing it to acceptable standards. Due to the sensitivity of coral reefs to pollution, particularly nutrient pollution, wastewater treatment standards and disposal practices need to be higher than where many other types of ecosystems are present.

Unfortunately, Fiji's legislation to protect or manage the environment is woefully inadequate and controls and regulations on waste discharges are effectively absent (Evans 2004). Although Environmental Impact Assessments (EIA) have been practiced for many tourist developments since the mid 1980s, these have been *ad hoc* in nature, with inadequate review and without monitoring of development conditions. Many resorts were constructed prior to this time when the need to minimize or prevent sewage effluent, whether treated or not, being discharged into coastal waters was little appreciated. Hampered by the lack of suitable legislation, there subsequently has been little governmental agency commitment to upgrade existing waste disposal practices. Also there is no independent agency consistently monitoring water quality around Fiji's coastal waters. It is largely up to the individual resort owner/company whether they choose to commit to proper management of their waste. In saying this however, many resorts are responsible when it comes to waste management and recognize that it can in fact enhance a resort's occupancy if they acquire a reputation for being environmentally friendly and promoting a better marine environment surrounding the resort. Installing advanced sewage treatment systems (i.e. secondary and tertiary level) can be expensive, but the long-term cost to a resort of a degraded environment could potentially be much higher. A number of resorts, have already seen the deterioration of their beachfront coral reef, and are aware that action is needed. It is hoped that this report will help to inform as to what is the current state of wastewater treatment in the Fiji tourism industry and to offer best-practice suggestions for improvement.

Sewage Treatment

Wastewater treatment for the purpose of the current study was defined into the categories primary, secondary, tertiary, and additionally whether disinfection (killing of bacteria) was carried out. These are explained in more detail below:

Primary treatment consists of the separation of liquids from solids. Typically, the raw wastewater first passes through some grates and screens to remove large pieces of trash and debris. The wastewater then flows to sedimentation tanks or clarifiers where both floatable and settleable solids are removed. Floatable solids are skimmed off the top of the water and settleable solids settle to the bottom of the clarifier. Periodically the settleable solids (sludge) at the bottom of the tank are disposed of or dried and used as compost. The septic tank is an example of primary treatment. A septic tank removes many of the settleable solids, oils, greases and floating debris in raw wastewater. Different types of septic tanks are used in Fiji, typically sealed one or two chamber tanks and unlined coral rock ones. Other examples include rectangular and circular settling tanks (UNEP 2002). After primary treatment, which reduces the Suspended Solid and Biological Oxygen Demand (BOD) concentrations, the wastewater still contains substantial concentrations of suspended organic waste solids, and both the solids and the water contain very high concentrations of faecal coliform and other types of bacteria. Further solids and bacteria removal occurs during secondary treatment.

Secondary treatment basically consists of some form of biological process. Bacteria are used to break down the organic waste left after primary treatment so that the effluent is suitable for discharge. Widely used processes that use aerobic bacteria include trickling filters, activated sludge and oxidation ponds. The activated sludge process is more efficient but also more complicated and energy intensive. Constructed wetlands provide an advanced form of secondary treatment which further removes nutrients, as do nitrification (conversion of ammonia to nitrate)/denitrification (removal of nitrogen in gaseous form) units which are available commercially (e.g. special Enviroflow units).

Tertiary treatment can be used to convert secondary treated wastewater into water that is (theoretically) good enough to drink or a higher quality than that of secondary treatment. The main objective is the removal of fine organic suspended solids. The processes used in tertiary treatment include reverse osmosis and microfiltration which remove very small particles, including bacteria and viruses. Others involving biological action include tertiary ponds and wetlands (UNEP 2002).

Disinfection: Disinfection is the killing of bacteria in the sample which reduces the human health risk when the effluent is discharged into the sea or sprayed onto land. Wastewater can be disinfected using ultraviolet light, ozone, or chlorine. Disinfection, if performed, usually follows secondary or tertiary treatment.

Table 1. below describes some of the systems in more detail.

Table 1. Different types of wastewater treatment systems used by resorts in Fiji and their characteristics

Type	*Description*	*Photo/Diagram*
Septic Tank	Consists of a tank underground which usually has two compartments and is connected to a flush toilet. The first is larger than the second. Heavy particles form a sludge layer at the bottom of the tank whilst less dense materials float forming a scum layer. Organic matter is digested by bacteria. Sludge should be removed regularly depending on the size and use of the tank. The tank is often connected to a seepage pit.	Appendix B Figures C &D, Appendix D Figure 3
Seepage/Soak Pit	This is designed for the disposal of sewage effluent (primarily from septic tanks) or greywater and consists of an underground pit filled with rocks or coral blocks through which the effluent percolates into the soil.	
Composting Toilet	This is a waterless toilet where excrement is collected and decomposes in a holding tank through a complex bio-chemical interaction of factors such as temperature, pH and biological action over time. Dry leaves or wood shavings need to be regularly added. Waste is regularly removed when sufficiently decomposed as compost which can be used as a soil fertilizer.	Appendix D Figure 2
Municipal Sewer System	Consists of the collection of sewage from sources (hotels, houses etc) by an underground pipe system that takes it to treatment facilities. The system normally includes pump stations to convey the sewage through the system. It is often the method of wastewater disposal in or near urban areas. Adequate treatment should be carried out prior to large point sources discharge.	Appendix B Figure A, Appendix D Figure 1
Activated Sludge Tanks	Following the primary settling of solids, wastewater goes into tanks where it is mixed with a bacteria-containing sludge and air. The bacteria break down a large percentage of the organic waste. It is then allowed to settle in a secondary treatment clarifier. Wastewater overflows from the secondary treatment clarifier to an outfall or to tanks where it is stored as reclaimed water. Settled solids from the secondary treatment clarifier are sent to a sludge digester or drying beds.	Appendix B, Figures M & N, K & L
Oxidation/Algal Ponds	These are fairly large ponds where organic matter is consumed by biological organisms using oxygen. The oxygen is supplied by the growth of algae. The ponds should be half filled with water before use.	Appendix B Figures I & J, Appendix D Figure 4
Constructed Wetlands	Suitable for wastewater that has undergone secondary treatment. The pond should be lined with clay or other lining to prevent groundwater contamination and then filled with soil and planted with reeds or with aquatic plants. When wastewater runs through the root zone organic compounds are removed by the microorganism and nutrients taken up by the plants.	Appendix B Figures G & H
Trickling Filter	Consists of tanks where wastewater is sprayed over a bed of rocks or plastic media that are coated with a slimy layer of bacteria that eats organic waste.	Appendix B Figure F, Appendix D Figure 5

(UNEP 2002).

Methods

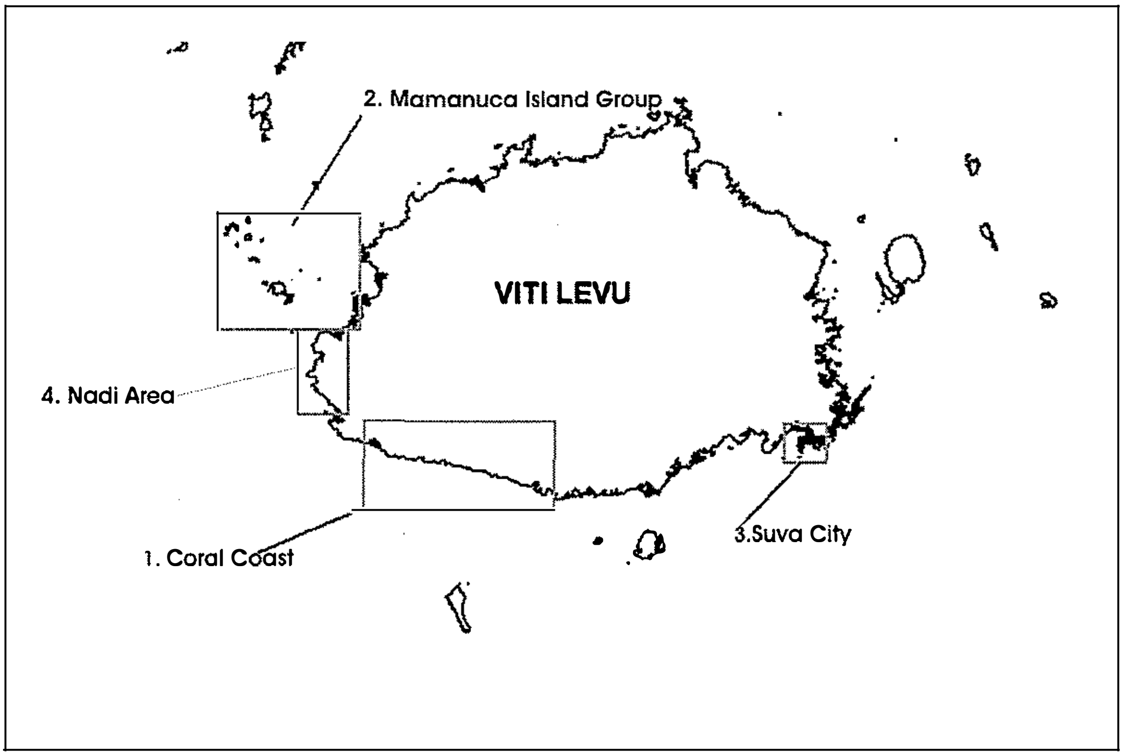
The study was undertaken by the Institute of Applied Sciences in March 2004 with support and assistance from the Fiji Ministry of Health (MOH), Department of Environment (DOE) and the Native Land Trust Board (NLTB). The general study locations selected (Fig. 1) were:

1. An area known as the 'Coral Coast' situated on the south of the main island of Viti Levu.
2. The Mamanuca Island Group, to the west of Viti Levu
3. The major city of Suva
4. The Nadi area including Momi Bay to the south.

The study focused mainly on hotels and resorts in the Mamanuca Islands and Coral Coast as these are major tourism areas where reef degradation has been observed. The study comprised of:

- Distribution of a survey questionnaire
- Site visits to some of the resorts to sample effluent discharges
- An expert review of results

Figure 1. The island of Viti Levu showing the study locations



Liquid Waste Survey Questionnaire

The main aim of the questionnaire survey was to determine how hotels and resorts manage their wastewater (freshwater, greywater and sewage) discharges and whether they had upgraded or were planning to upgrade their liquid waste treatment facilities.

The questionnaire survey was FAXed or delivered to 50 resorts located in coastal areas throughout Fiji to determine the standard of their wastewater treatment (Appendix 1). In addition to resorts within the main study areas mentioned above, surveys were also sent out to resorts in Lautoka, Rakiraki, Vanua Levu and Taveuni. Motels and backpackers were not included.

Twenty one of the resorts were inspected by the study team and in these cases the questionnaires were filled out on-site with the engineer or appropriate person. Other resorts not visited were followed up with a phone call and reFAXed.

The following hotels/resorts completed the questionnaires:

Coral Coast: Shangri La Fijian, Outrigger Reef, Tubakula, Tambua Sands, Hideaway, Naviti, Warwick, , Bedarra Inn

Mamanuca/Yasawa Islands: Treasure Island, Beachcomber, Tokoriki, Mana, Navini, Castaway, Musket Cove, Plantation, Tavarua, Vomo

Suva/Beqa: Holiday Inn, Raffles Tradewinds, Lalati Resort

Nadi/Momi Bay: Sheraton Fiji, Sheraton Royal, Sheraton Villas, Sonaisali, Seashell Cove, Grand West Villas

Lautoka: The Waterfront

Other: Wananavu Resort, Lomalagi Resort

Effluent Sampling

Effluent sampling was undertaken at 18 of the resorts inspected. Health inspectors from the Ministry of Health (MOH) accompanied us on these inspections with a staff member from the Department of Environment (DOE) also coming for hotels in the Suva area. MOH officers have legislated rights of inspection, and are responsible for monitoring water quality and wastewater treatment of hotels, resorts and industry under the aegis of the Central Board of Health. In most cases, hotels were agreeable about being sampled. At each resort either the engineer or relevant person was contacted to show us around the facility and provide us with information regarding the wastewater management at the resort.

Usually only a single sample was taken from the final stage of wastewater treatment from each resort. For five of the resorts more than one sample was taken, either before and after treatment had taken place or when there were multiple discharges of a different nature to the sea (e.g. kitchen, toilet, laundry waste). We attempted to collect the effluent that reaches the coastal environment, although some resorts spray their final effluent on land which would provide some further treatment. Some samples were collected from the second-chamber of septic tanks before the waste flows to a soak pit. For some resorts, samples were taken from the main sewer line leading from the resort to the municipal treatment plant.

Samples were collected in a plastic jug that was dipped into the waste stream. Temperature and dissolved oxygen measurements were performed at the time of sampling using a calibrated handheld meter (YSI 85). Samples were immediately stored on ice for transport back to the laboratory in Suva and placed under refrigeration at 4°C until analysis. Certain parameters (faecal coliforms, ammonia, Biochemical Oxygen Demand) were analysed within 24 hours of sampling to minimize any changes in their concentrations while in storage.

Effluent Analyses

Analyses of the several water quality parameters were made at the Institute of Applied Sciences (IAS) laboratory at the University of the South Pacific using internationally accepted methods (APHA, 1998). Quality control procedures were undertaken to ensure the data were of acceptable quality. These procedures included the running of blanks, standards and standard reference materials where possible. Often samples were required to be diluted to provide concentrations in the correct range for a particular method. The following parameters were analysed in the laboratory:

pH is a measure of how acidic or basic the effluent is. A pH between 8-8.5 is preferable to protect the marine environment (ANZECC 2000). pH was measured using a calibrated glass electrode (APHA 1998 method 4500-H^+ B).

Biochemical Oxygen Demand (BOD) is a measure of the oxygen requirements of a sample which is determined by the amount of organic material present which consumes oxygen when it is broken down by bacteria. BOD was determined by measuring the oxygen content before and after incubation of a diluted sample for 5 days at 20°C (APHA 1998 method 5210 B). BOD was analysed instead of COD (Chemical Oxygen Demand) as effluent from resorts is more likely to contain large amounts of organic matter from sewage and kitchen waste as compared to chemical waste, which is more significant in industrial effluent.

Total suspended solids (TSS) is a measure of how many suspended particles are present in a water sample. When discharged directly to the marine environment, high amounts of suspended solids can smother and kill coral reef organisms. TSS was measured by weighing the amount of solids collected upon filtering a known volume of sample (APHA 1998 method 2540 B).

Faecal Coliform bacteria are a measure of the risk to human health from drinking, bathing or swimming in water that contains human sewage effluent. Faecal coliforms were measured by first collecting the bacteria in a diluted sample by membrane filtration, placing the filter on a specific agar plate, incubating at a set temperature, and then counting the colonies which have grown (APHA 1998 method 9222 D).

Several different forms of nitrogen and phosphorous were measured (total nitrogen, organic nitrogen, ammonia, nitrate and nitrite; Total phosphorus, dissolved phosphate). These compounds when present in seawater provide nutrients for the primary producers (plants) such as phytoplankton, algae and seaweeds.

Total Nitrogen (TN) was estimated by calculating the sum of all the nitrogen species measured (organic nitrogen, ammonia, nitrate and nitrite).

Organic nitrogen (Org. N) was measured by first measuring the Total Kjeldahl Nitrogen (TKN) which includes organic nitrogen and ammonia, and then substracting the results from separate ammonia determinations. TKN was determined by titration after a hot sulfuric acid and persulfate sample digestion, and distillation and collection of ammonia (APHA 1998 method 4500-N_{org} C).

Ammonia was analysed using a distillation and titrimetric method (APHA 1998 method 4500-NH_3 B&C).

Nitrate and nitrite were measured on filtered samples by colorimetry following passage through a cadmium reduction column (APHA 1998 method 4500-NO_3^- E).

Total Phosphorus was measured on unfiltered samples by colorimetry, following a hot acid-persulfate digestion (APHA 1998 method 4500-P B&E). Dissolved Phosphate was measured on filtered samples by colorimetry using standard methods (APHA 1998 method 4500-P E).

External Wastewater Treatment Expert Review

An external wastewater expert, (Mr. Graham Wallace, Tonkin and Taylor, New Zealand) was asked to review the results to provide a perspective based on internationally accepted best-standards. The review is included in the discussion.

Results

Questionnaire Results

The response rate to the questionnaire was 60% or 30 responses out of the 50 that were sent out. The results are summarized in Table 2 and in Appendix C.

Table 2. Summary of questionnaire survey results (number and percentage of responses)

Land Tenure	Responses	Percentage
Crown	2	6.7
Native	18	60
Freehold	9	30
No response	1	3.3

Freshwater Source*	Responses	Percentage
Municipal supply	12	40
Rainwater collection	9	30
Borehole	6	20
Desalination plant	5	16.7
River/Creek	3	10
Spring	1	3.3
Barge	2	6.7

* Some resorts had more than one water source

Recycle Greywater	Responses	Percentage
Yes	11	36.7
No	18	60
No response	1	3.3

Greywater Disposal*	Responses	Percentage
Into soak pits	8	30.8
Septic Tanks	2	7.7
Sewer Line	7	26.9
Sewage Treatment Plant	6	23.1
Ocean	2	7.7
Creek	1	3.8

* Only for those that did not recycle all greywater. Some resorts had more than one method of disposal

Other discharge into Ocean	Responses	Percentage
Stormwater	10	33.3
Pool backwash	7	23.3
Kitchen water	1	3.3
No other discharge	12	40

Use of phosphate free detergents	Responses	Percentage
Yes	12	40
No	17	56.7
No response	1	3.3

Toilet Type*	Response	Percentage
Freshwater Flush	23	76.7
Saltwater Flush	5	16.7
Composting	1	3.3
Recycled Water/Effluent	2	6.7

* Some had more than one toilet type

Type of Sewage Treatment*	Responses	Percentage
Municipal Sewer	8	26.7
Sewage Treatment Plant	12	40
Septic Tanks	12	40
Composting	1	3.3

* Some resorts had more than one type of treatment

Sewage Treatment Plants

Treated Effluent Reused	Responses	Percentage
Yes	7	53.8
No	6	46.2

* One resort recycled back their sewage effluent from the municipal sewer

Discharge of Sewage Effluent from Treatment Plant	Responses	Percentage
Gardens/golf course	6	50
Ocean	3	25
Creek	1	8.3
Natural Wetland	1	8.3
Stored	1	8.3

Frequency Treatment Plant Monitored	Responses	Percentage
Hourly	2	16.7
Daily	9	75
Weekly	1	8.3

Effluent Quality Tested	Responses	Percentage
Yes	7	53.8
No	6	46.2

Disposal of Solids from Treatment Plant	Responses	Percentage
Pumped out and taken to municipal treatment plant	4	33.3
Pumped out and buried on-site	3	25
Dried and used on gardens	2	16.7
No sludge	2	16.7
Barged to mainland	1	8.3

Septic Tanks

Discharge of Effluent	Responses	Percentage
Soak pits	9	75
Pumped to treatment plant	2	16.7
Pumped out and taken to municipal treatment plant	1	8.3

Frequency Sludge Removed	Responses	Percentage
Every 2-6 months	4	33.3
Once a year	3	25
Every 2-7 years	3	25
Do not remove sludge	2	16.7

Disposal of Solids	Responses	Percentage
Waste management company to municipal treatment plant	8	66.7
Pumped out and buried on-site	4	33.3

Municipal Sewer Usage

Location of Treatment Plant	Responses	Percentage
Kinoya	1	12.5
Olosara, Sigatoka	2	25
Navakai, Nadi	4	50
Natabua, Lautoka	1	12.5

Management of Liquid Waste

Upgraded Treatment System in Last 7 years	Responses	Percentage
Yes	11	36.7
No	19	63.3

Type of Upgrade	Responses	Percentage
Maintenance	3	27.3
Upgraded Treatment Plant	4	36.4
Upgraded septic tanks	3	27.3
Connected to sewer system	1	9.1

Satisfied with Current System	Responses	Percentage
Yes	22	73.3
No	7	23.3
No response	1	3.3

Planned Upgrades	Responses	Percentage
Yes	11	36.7
No	18	60
No response	1	3.3

Land Tenure

Most of the resorts (60%) surveyed held native lease on the land they occupied, 30% occupied freehold land and two held crown leases.

Freshwater Usage

The major sources of freshwater for hotels and resorts in the survey were from municipal water supplies (40%), rainwater collection (30%), and borehole (20%). A few resorts utilized desalinators

(16.7%), creek or river water (10%) and two of the island resorts barge water from the mainland when required. Those that have desalinators were on islands and those that used creek water had a small dam and water purification system. Seven resorts (24.1%) use at least two water sources. Results are similar to those of the Greenpeace survey where 60% of resorts used municipal water supplies.

Estimates of freshwater usage ranged between 1,000 L/day for the smaller resorts to 1.2 million L/day (1,200 m^3 per day) for the larger resorts. On a per room basis, many resorts used greater than 1000 L/room/day of water. Most of the resorts reported high use of freshwater for showers and sinks, medium use for toilets, laundry and kitchens, and lower usage for pools and gardens. Four resorts had saltwater pools instead of freshwater.

Most of the resorts surveyed used freshwater flush toilet systems (76.7%). Several, particularly on islands used saltwater flush systems (16.7%), two used recycled effluent in their toilets and one used composting toilets.

Greywater Management

Many (36.7%) of the resorts did reuse greywater (laundry, shower, sink, stormwater etc) for irrigation on gardens or golf courses and one resort used it to flush toilets. Resorts that did not reuse greywater discharge it mainly into soak pits (30.8%), to septic tanks (7.7%) to their sewage treatment plant (23.1%) or into the municipal sewer line (26.9%). Two resorts discharged their greywater into the ocean and one into a creek. Many resorts (33.3%) reported that they also discharge stormwater runoff into the ocean and 23.3% reported discharge of pool backwash into creeks or the ocean. As compared to the Greenpeace survey, where only 17% of resorts reused their greywater, these results may indicate that more resorts are now reusing greywater as a means of minimizing freshwater usage and to decrease the volume of wastewater to be discharged

Many of the resorts surveyed (40%) did use some type of low or non-phosphate detergents in their operation indicating that these products are available in Fiji for use in the tourism industry.

Sewage Treatment Methods

Most of the resorts surveyed had sewage treatment plants (40%) or septic tanks (40%) while others were connected to the municipal sewer system (26.7%) and one utilized composting toilets. A few resorts had septic tanks with the out-flowing effluent then pumped to a treatment plant. If we consider septic tanks as primary treatment, 50% of resorts have a primary level of sewage treatment and 23% have secondary level of treatment. If this is compared to the Greenpeace survey where 66% of resorts had primary treatment and 7% secondary, these results could indicate the movement towards better level of sewage treatment amongst resorts located in coastal areas in Fiji.

Most of the resorts surveyed could not provide an estimate for the volume of wastewater produced daily. The freshwater usage figures supplied by many resorts, however, give a good indication of the volume of effluent generated each day. Estimates of the wastewater volume generated are about 70-90% of the freshwater usage. Therefore we estimate an average wastewater generation of about 700-900 L/room/day or for the resorts sampled as a percentage of their freshwater usage per day (see Table 4). Rapaport 1996b estimates 66-95 litres per person per day produced as sewage wastewater (see Table below). However this volume seems to be an underestimate since it includes only sewage effluent and not total wastewater produced.

Table 3. Size of resorts surveyed based on number of rooms (small <50 rooms, medium 51-100 rooms, large >100 rooms) and estimated volume of sewage effluent produced per day based on average occupancy and figure of ~80 litres/person/day

Resort	No. of Rooms	Size	Max Capacity	Av. Occupancy (%)	Average Person Capacity	Minimum Effluent Produced/Daily (m^3)
A	**108**	**Large**	**216**	75	162	13
B	**130**	**Large**	**220**	**78**	171	13.7
C	**436**	**Large**	**1400**	**64**	896	71.7
D	**110**	**Large**	**220**	**75**	165	13.2
E	**250**	**Large**	**700**	**78**	546	43.7
F	**25**	**Small**	**80**	**50**	40	3.2
G	**140**	**Large**	**400**	77	308	24.6
H	**23**	**Small**	**100**	**NR**	~70	5.6
1	**254**	**Large**	**500**	**71**	355	28.4
J	**155**	**Large**	**341**	**40**	136	10.9
K	**67**	**Medium**	**170**	**80**	136	10.9
L	**22**	**Small**	**180**	**80**	144	11.5
M	**34**	**Small**	**60**	**85**	51	4.1
N	**63**	**Medium**	**250**	**85**	212	17
O	**80**	**Medium**	**160**	**50**	80	6.4
Q	**140**	**Large**	**450**	**60**	270	21.6
R	**NR**	**Small**	**85**	**55**	46	3.7
S	**123**	**Large**	**260**	**85**	221	17.7
U	**300**	**Large**	**900**	**71**	~639	51.1

NR = No response

Sewage Treatment Plants

For the resorts with sewage treatment plants, five resorts had primary level of treatment plants while seven had secondary level of treatment. No resorts had what we consider to be tertiary treatment in place. Two of the resorts had Enviroflow Biological Treatment Systems consisting of a trickling filter while the others had a variety of components including aeration and settling ponds, and activated sludge plants. Seven resorts used chemicals (either chlorine or a chemical to break up solids) in their sewage treatment.

Fifty-three percent of resorts that treated their effluent reused it including one resort that piped effluent back from the municipal plant. Recycled sewage effluent was used to irrigate gardens or golf courses. Those resorts that had treatment plants but did not recycle effluent either discharged to the ocean (25%), a creek (8.3%), natural wetland (8.3%) or stored to be pumped out and taken to the municipal treatment plant (8.3%). It should be noted that the few resorts that discharged sewage effluent directly into the ocean were only of primary treatment level. Many of the resorts had the solids from their treatment plant pumped out to the municipal treatment plant (33.3%) while others pumped it out and buried it on land themselves (25%), or dried the solids and used it in gardens (16.7%). Two resorts indicated that the removal of sludge was not required for their treatment plant.

Sewage treatment plants were fairly regularly monitored with 75% being monitored daily, 16.7% hourly and 8.3% weekly and around half of the resorts do have their sewage effluent quality tested (53.8%). These tests are usually carried out by a recognized laboratory such as IAS and are for the record of the resort only. Most tests were for faecal coliform levels only.

Septic Tanks

The septic tank was one of the most commonly used primary wastewater treatment units for smaller resorts in the Fiji Islands. However some large resorts had septic tanks which were connected to their sewage treatment plants. Most resorts had two chamber septic tanks with the first chamber being a holding tank for solids and the second chamber holding liquid effluent. The number of septic tanks at each resort ranged between 3-11. For most of these resorts the effluent from the septic tanks flowed into soak pits nearby (75%) while a few pumped the effluent to their treatment plant (16.7%) and one pumped the effluent out to be taken to the municipal treatment plant.

The frequency of removal of sludge from septic tanks varied with 33.3% of resorts with septic tanks having it removed every 2-6 months, 25% removing it once a year, 25% removing it only every 2-7 years. Two resorts did not remove the sludge at all. Frequency would also vary according to the size of the septic tanks and size of the resort. Most resorts had a waste management company remove the solids and dispose of them at the municipal treatment plant (66.7%) while others (33.3%) pumped the solids out themselves and buried them on-site.

Other Systems

Of the eight resorts that used the municipal sewer system, 50% connected to the treatment plant at Navakai, Nadi, 25% to Olosara treatment plant in Sigatoka, 12.5% or one to Kinoya treatment plant in Suva and 12.5% or one to the Natabua treatment plant in Lautoka. These Sewage Treatment Plants are operated by the Public Works Department and are all secondary treatment plants. One resort utilised composting toilets which were emptied monthly on their gardens. Composting toilets are categorized on their own but are probably at least of secondary treatment level.

Upgrade and Management of Wastewater Treatment Systems

Many (36.7%) resorts indicated that they had carried out modifications or upgrades to their wastewater treatment systems in the last 7 years. Around 36% had upgraded their treatment plants (constructed a more advanced plant or improved their existing plant), 27.3% upgraded their septic tanks to larger or more efficient tanks, 27.3% had undertaken maintenance to their treatment plant, and one had connected to the sewer system. Most resorts were happy with their current wastewater treatment systems (73.9%) while 36.7% indicated that they were planning to upgrade.

To determine whether the awareness of the resort managers on the necessary degree of wastewater treatment corresponded to the standard of treatment at the different resorts a comparison was done for the resorts where effluent was sampled. It was found that all the resorts that were connected to sewer systems were happy with their treatment systems and almost all those using septic tanks were also happy with their treatment. Of the resorts that had a good level of wastewater treatment all were happy with their treatment, and two were planning to further upgrade. Of the resorts with a poor level of wastewater treatment half understood the need for an upgrade of their systems whilst half were happy with their treatment, thus not understanding the poor standard of wastewater being produced by their resort

Resort Inspections and Effluent Sampling Results

A summary of the type of wastewater treatment, method of effluent discharge, and description of the point of sample collection for resorts which were inspected is listed in Table 4. It is noted that individual hotels/resorts are not identified alongside samples results in this report as was agreed at the commencement of the study. This information is confidential and a letter code is given for individual resorts.

Table 4. Summary of resort sewage treatment and discharge

(* 1° stands for primary which includes septic tanks, 2° for secondary and + for those resorts that also had wetlands)

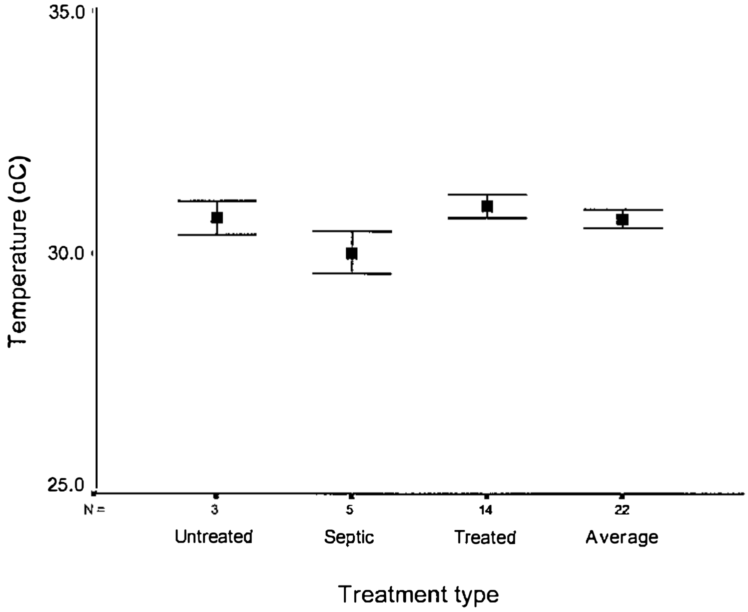
Resort ID	Degree of Treatment*	Treatment Details	Discharge	Sample ID and description of point of sample collection
A	1°	Settling, basic aeration	Pumped out by wastecare and taken to municipal treatment plant	A: Treatment plant, final chamber wastewater
B	None	None	Pumped to municipal treatment plant	B: Main sewer line from hotel
C	2° +	Activated sludge, settlement pond, wetlands	Golf course, garden irrigation	C: Final irrigation pond after wetland
D	1°	Septic tanks	Soak pits	No sample
E	1°	Settling, basic aeration	Ocean	E: Treatment plant raw wastewater
F	1°	Septic tanks	Soak pits	F: 2nd chamber of septic tank to a couple of bures
G	1° +	Settling, basic aeration, ponds	Excess effluent discharged to creek, ocean	G1: Treatment plant raw wastewater G2: outflow from ponds on golf course to creek
H	1°	Septic tanks	Soak pits	H: 2nd chamber of septic tank to a bure
I	2°	To municipal treatment plant, effluent back to pond on resort	Irrigation	I: Irrigation storage pond
J	2°+	Activated sludge, wetlands	Garden irrigation	J1: outflow from treatment plant wastewater J2: wetland water
K	1°	Mascerator	Ocean	K: Storage tank before discharge
L	2°	Activated sludge	Garden irrigation	L: Final treatment plant effluent
M	1°	Septic tanks	Soak pits	M1: septic tank from bure M2: septic tank from kitchen

Resort ID	Degree of treatment	Treatment Details	Discharge	Sample ID and description of point of sample collection
N	2°	Activated sludge, UV disinfection	Forest irrigation	N: Final UV-disinfected treatment plant effluent
O	2°	Settling tank, trickling filter, Enviroflow system	Grass irrigation	O1: Settling tank raw effluent O2: Treated final effluent after trickling filter
P	1°	Septic tanks	Soak pits	No sample
Q	2°	Septic tanks, settling tank, trickling filter (Enviroflow), ponds	Irrigation	Q1: Incoming effluent to treatment plant (septic tank treated) Q2: Irrigation pond water
R	1°	Septic tanks	Soak pits, some to creek	R: 2nd chamber of septic tank
S	1°	Septic tanks, ponds	Land, some to ocean	S: Final treatment pond effluent
T	None	None	Pumped to municipal treatment plant	No sample
U	None	None	Pumped to municipal treatment plant	U,V: Combined wastewater from 2 resorts
V	None	None	Pumped to municipal treatment plant	U,V: Combined wastewater from 2 resorts
Y	1°	Septic tanks	Soak pits	No sample

The analytical results from the effluent samples are shown in Table 5, divided up into sections for the different types of treatment methods, and shown in the figures below.

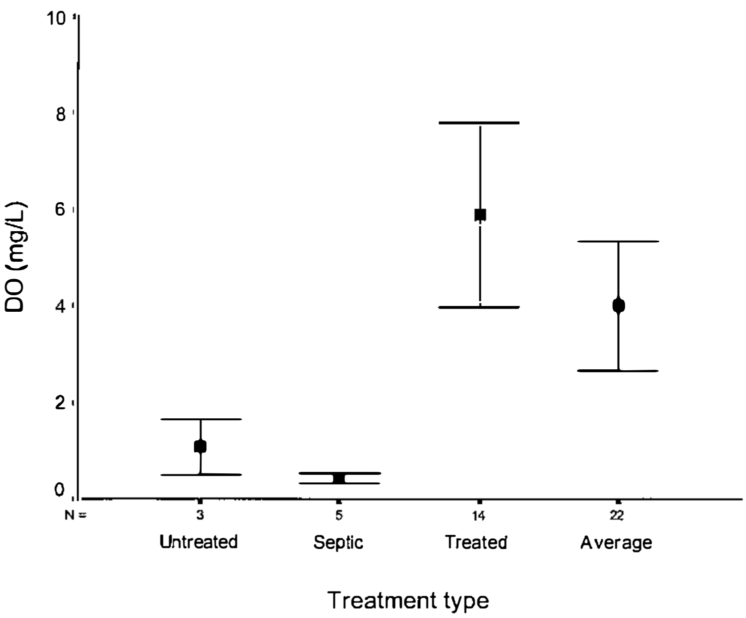
The temperature of the effluent at different locations was relatively constant at around 31°C reflecting the ambient air temperatures (Figure 2). The pH of the effluent showed more variability with an average of pH 7.7. The wastewater from a couple of resorts (I, S) had high pH values (>10) as did the one sample of laundry wastewater (G3). It is unclear why the pH was so high in these resorts' wastewater unless caustic soda was being used, but this was not noted in the questionnaire.

Figure 2. Average temperature and standard error for the various types of waste treatment



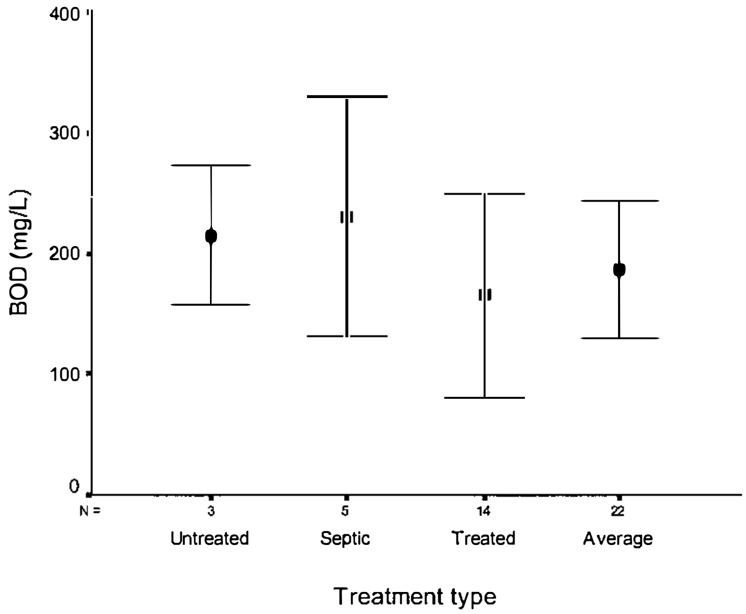
The dissolved oxygen content was quite variable (Figure 3). Generally, primary treated/septic tank effluent had very low oxygen values (<1 mg/L) while as expected effluent which had been aerated (e.g. N) had higher values. Some of the resorts with open treatment ponds (C,I,S) had very supersaturated oxygen values (>15mg/L) which must be due to the large amount of green algae in the ponds photosynthesizing and producing oxygen into the water.

Figure 3. Average dissolved oxygen and standard error for the various types of waste treatment



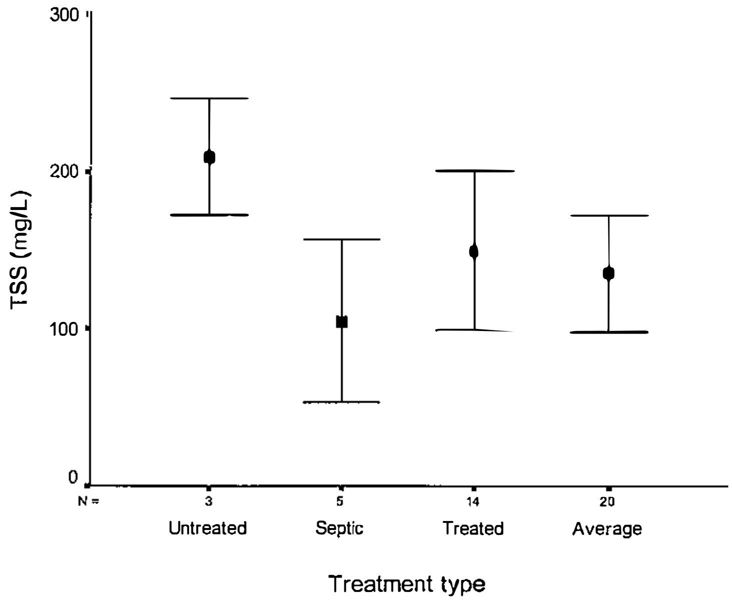
The BOD (Biological Oxygen Demand) in the untreated and septic tank effluent was quite high, although similar to values elsewhere (Table 6), and the kitchen effluent (M2) was very high (Figure 4). This indicates that a large amount of organic material was present in these samples which consumed oxygen as it was broken down by bacteria. BOD values in the secondary treated effluent from some resorts (e.g. G1,O1,Q1) were much lower compared to their untreated effluent (c.f. G2,O2,Q2), This shows the effectiveness of aeration and bacterial decomposition processes to breakdown the BOD. Some resorts (C,I,J,S) which pump their wastewater into ponds/wetlands also had very low BOD values in their final effluent. This is because ponds offer further settling of particles in the wastewater and allow bacteria further time to break down organic material.

Figure 4. Average BOD and standard error for the various types of waste treatment



Total suspended solids (TSS) results were variable but generally reflected the degree of wastewater treatment. The untreated wastewater had the highest TSS values with basic septic tank or settlement treatment producing a reduction of about 50% on average. Resorts with ponds in the final stage of the wastewater treatment generally had quite low TSS values although one resort (G2) had high values, possibly a result of the algal material present (Figure 5.).

Figure 5. Average Total Suspended Solids and standard error for the various types of waste treatment



Total nitrogen in the treated effluent was on average much lower than the untreated or septic tank effluent (Figure 6). Organic nitrogen showed a similar trend as did ammonia, which was the major nitrogen compound present (Figure 7). This indicates that the treatment processes appear relatively effective at removing some portion of the nitrogen loading. Upon closer examination it is evident that the resorts with ponds or wetlands (C,I,S) have among the lowest nitrogen compound values. This is due to uptake of nutrients by the plants or algae in the ponds. Total phosphorus (TP) showed similar trends to nitrogen with about a 2/3 reduction on average when treatment was undertaken (Figure 8). Dissolved phosphorus (PO_4) values were quite similar between the different treatment systems while the resorts with ponds/wetlands had the lowest P values due to the reasons noted above.

Figure 6. Average Total Nitrogen and standard error for the various types of waste treatment

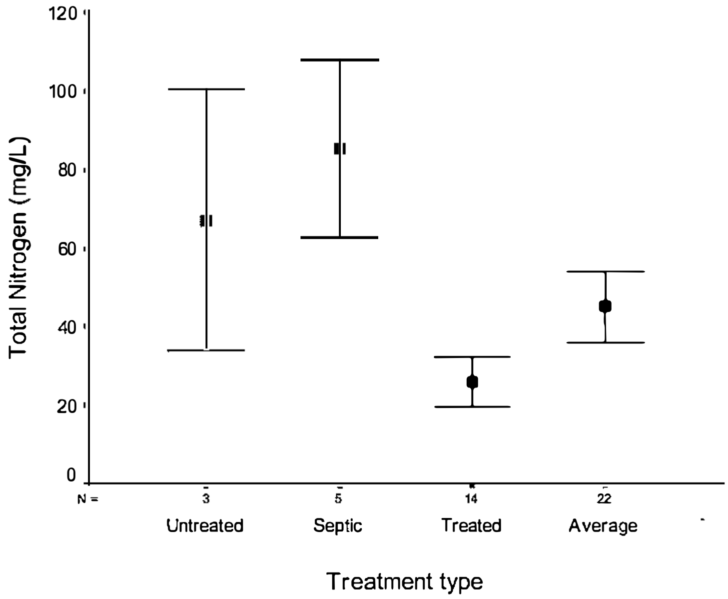


Figure 7. Average Ammonia and standard error for the various types of waste treatment

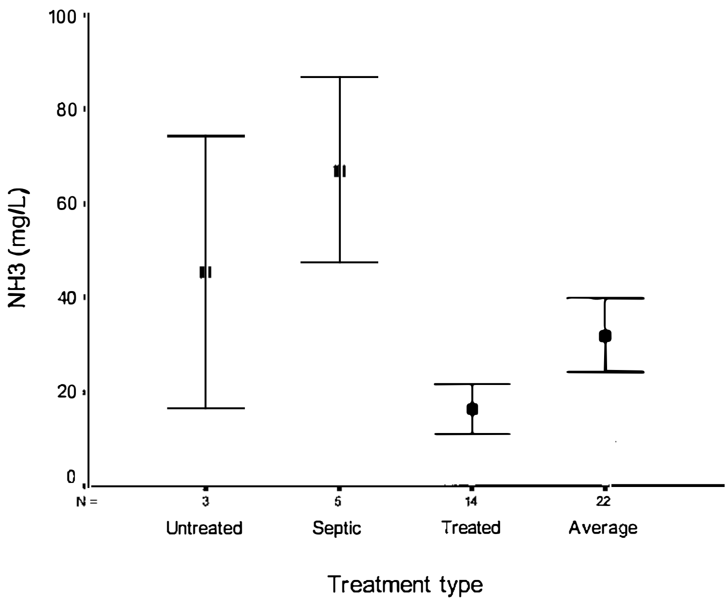
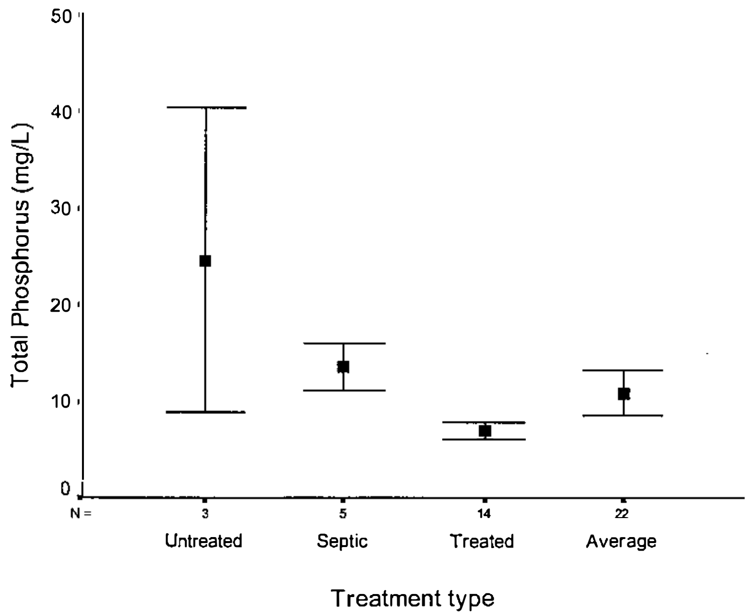
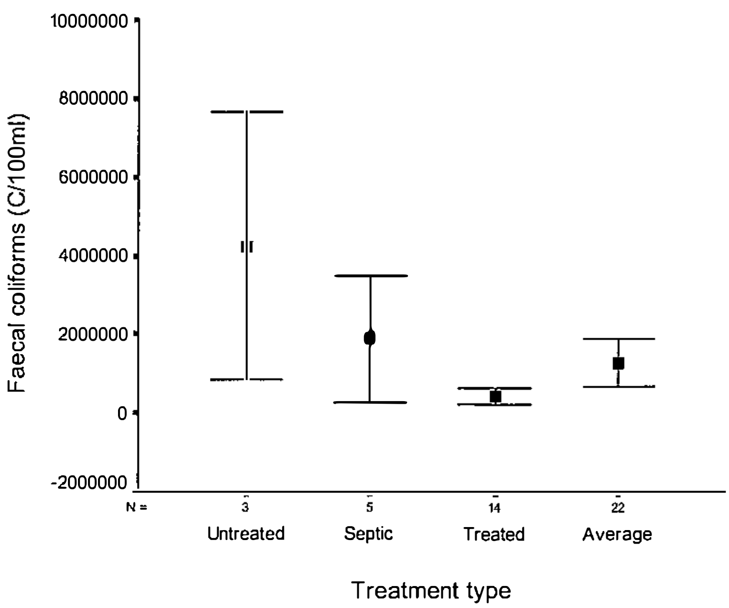


Figure 8. Average Total Phosphorus and standard error for the various types of waste treatment



Faecal coliforms were high on average in almost all the different treatment types except for ones with disinfection (O2) or with ponds (C, I, J, S) (Figure 9). Some resorts disinfection was ineffective (e.g. O for UV disinfection treatment) as high levels of bacteria were still present.

Figure 9. Average Faecal Coliforms and standard error for the various types of waste treatment



It should also be noted that the impact of wastewater discharged from resorts on the environment would not only depend on the standard of wastewater being discharged but also on the volume of effluent discharged into the environment each day as well as the characteristics of the receiving environment. As expected the large resorts would discharge a greater volume of wastewater into the environment thus having a greater impact. Estimates of volumes of wastewater discharged are included in Table 5.

Apart from individual monitoring of the standard of effluent by individual resorts, of which the results are normally confidential, no prior study on the standard of wastewater among resorts in Fiji has been undertaken thus this study would serve as a baseline for future studies to be compared to.

Table 5. Analysis results for liquid wastewater (T=temperature, DO=dissolved oxygen, BOD=biochemical oxygen demand, TSS=total suspended solids, TN=total nitrogen, Org.N=organic nitrogen, NH_3=ammonia, NO_3+NO_2=sum of nitrate and nitrite, TP=total phosphorus, PO_4=dissolved phosphate, FC=faecal coliforms, nd=not determined). *Note: for the treated effluent, the raw wastewater results taken for some resorts (G1,J1,O1) were not used in calculating the mean and standard deviation. * Note estimate of volume of effluent is based on 80% of freshwater used/day when not provided by resort*

ID	T	pH	DO	BOD	TSS	TN	Org. N	NH_3	NO_3+NO_2	TP	PO_4	FC	Volume*
	°C		mg/L	mg L	mg L	mg L	mg/L	mg L	mg L	mg/L	mg L	C/100mL	m^3/day
Untreated: Final effluent pumped/taken to municipal treatment plant													
B	31.0	6.9	0.3	286	271	40	27	13	0.04	56	0.6	1700000	56
A	31.1	7.3	0.7	100	142	133	30	103	0.2	12	10	40000	
U,V	30.0	6.8	2.2	259	215	28	8	20	0.08	5.8	3.6	11000000	640
Mean	*31*	*7*	*1*	*215*	*209*	*67*	*22*	*45*	*0*	*25*	*5*	*4246667*	
SD	*1*	*0*	*1*	*101*	*65*	*58*	*12*	*50*	*0*	*27*	*5*	*5907159*	
Septic Tanks													
H	28.5	8.0	0.8	49	54	153	8	120	25.1	15	10	11000	
F	30.5	7.5	0.4	122	55	33	<2	33	0.2	8.1	3	8300000	32
M1	30.0	7.6	0.3	<50	19	61	39.7	20.3	0.5	20	5.2	190	12
R	31.0	7.3	0.3	539	307	124	18	106	0.1	17	13	870000	
Q1	30.0	6.8	0.3	391	89	56	<2	56	<0.03	7.6	6.3	200000	
Mean	*30*	*7*	*0*	*275*	*105*	*85*	*22*	*67*	*6*	*14*	*8*	*1876238*	
SD	*1*	*0*	*0*	*229*	*116*	*51*	*16*	*44*	*12*	*6*	*4*	*3608520*	
Treated Effluent													
C	33.0	9.5	15.4	13	53	<3	<2	<1	<0.03	5.9	1	<100	700
E	31.0	7.0	0.4	195	263	25	16.5	7.5	0.6	11	3.8	610000	220
1	32.2	10.7	>20	10	65	<3	<2	<1	0.06	0.8	0.4	92	270
G1	30.0	7.3	2.2	112	51	59	29	24	5.6	4.2	4	1200000	
G2	30.0	7.1	2.5	71	535	20	<2	19.3	0.6	4.6	3.9	790000	120
L	30.0	7.3	2.2	<40	60	21	11	9	0.6	8.2	3.4	330000	50
K	29.6	7.6	0.4	<500	134	18	<2	18	0.1	8.6	7.6	36000	80
N	31.2	7.4	5.9	108	10	<3	<2	<1	0.5	8.6	2.6	120000	800
O1	31.0	7.0	0.3	1160	569	74	15	58	0.6	9.9	6.7	2800000	
O2	31.0	7.2	2.1	<20	32	62	<2	61	0.6	12	6.6	<1	8
Q2	31.0	7.9	1.1	49	23	34	13	20	0.5	8.8	3.2	38000	—
J1	31.0	6.9	2.5	<10	20	18	8	4	5.6	4	3.9	74000	
J2	30.6	7.2	7.5	<10	12	4	<2	3.2	0.6	5.4	4.9	240	150
S	31.6	10.8	>20	16	43	17	16	<1	0.6	5.7	0.4	<1	50
Mean	*31*	*8*	*5*	*66*	*112*	*25*	*14*	*20*	*0*	*7*	*3*	*240542*	
SD	*1*	*1*	*5*	*67*	*158*	*17*	*3*	*19*	*0*	*3*	*2*	*306910*	
Kitchen Septic Tank													
M2	30.0	5.3	0.3	8440	4249	187	182.2	4.8	0.3	8.2	6.4	1200000	
Laundry Outflow													
G3		10.2		89	nd	13	<2	12.7	0.3	7.8	0.9	nd	
AVERAGE AND STANDARD DEVIATION FOR ALL RESULTS													
Mean	**31**	**7.7**	**2.3**	**653**	**307**	**56**	**30**	**37**	**2.0**	**11**	**4.7**	**1405692**	
SD	**1**	**1.3**	**3.7**	**1905**	**854**	**50**	**45**	**36**	**5.4**	**10**	**3.2**	**2863311**	

Comparison of Analysis Results with Recommended Standards

Effluent Standards

The analysis results for liquid wastewater from septik tanks and sewage treatment plants in Table 5 was compared against effluent discharge standards to determine adequacy of wastewater treatment methods. The variables considered are BOD (Biological Oxygen Demand), TSS (total Suspended Sediments), Total – N, Total – P, soluble P and Faecal Coliforms. The Standards used for making the comparison are as follows :

- European Union (EU) - CEC Directive concerning urban waste water treatment(91/271/EEC) Commission of European Communities, Off J L 135/40
- Wider Caribbean (WCR) - Caribbean Environment Programme Technical Report #40
- Jamaica - Natural Resources Conservation Authority (NRCA), National Sewage Effluent Regulations
- Queensland – Department of natural resources and Mines On-site Sewage Facilities, Guidelines for Effluent Quality
- Waikato, New Zealand – Environment Waikato, Waikato Regional Plan.
- Victoria, Australia – Guidelines for Environmental Management: Use of reclaimed water Environmental Authority
- NSW, Australia – NSW guidelines for urban and residential use of reclaimed water. NSW Recycled Water Coordination Committee
- WHO – Health Guidelines for the use of wastewater in agriculture and aquaculture. World Health Organisation Technical Report, Technical Report Series 778

The use of reclaimed water (treated effluent) is divided into unrestricted and restricted use. Unrestricted use covers washing water, toilet flushing, water features such as ponds and fountains whereas restricted use covers primarily the use for irrigation of gardens, lawns, golf courses etc.

BOD (Biological Oxygen Demand)

Table 6 shows the effluent standard for sewage discharges for BOD from a range of countries compared with the results obtained from the sampling of sewage treatment plants at resorts in this study.

Table 6. Comparison of Mean BOD values with Effluent Standards (mg/l unless otherwise stated).

Mean BOD Survey Results		**BOD Standards for treated effluent Discharge**				
Fijian Septic tank	**Fijian Secondary Treatment**	**EU**	**Jamaican**	**Victoria**	**Queensland**	**Waikato**
275	66	25	15 (1)	20 (2) 5 (3)	20	20
Resort plants complying (mg/l)		C(13), I(10) , O(<20), J(<10), S(16)				
Resort plants not complying (mg/l)		E(195), G(71) ,L(<40), K(<500), N(108), Q(49)				

1 – irrigation water value
2- for secondary treatment
3 – for new tertiary plants

Table 6 shows that 5 of the 11 sewage treatment plants produced effluent of an acceptable standard in respect of BOD, i.e. 20mg/l or less. The Queensland standard for effluent discharges for BOD from a septic tank outlet is 120 to 240 g/m^3 or 120 to 240 mg/l. Of the 5 septic tanks tested tanks H,F and M meet the standard while tanks R and Q failed. The standards for the unrestricted reuse of treated wastewater in Australia varies from state to state with a range of between <20mg/l and <10 mg/l. The BOD standards for restricted use varies from no standard down to 20mg/l. All of the complying plants identified in Table A would meet the 20mg/l standard for both restricted and unrestricted use.

TSS (Total Suspended Solids)

The mean results for TSS from the survey are compared against effluent discharge standards in Table 7.

Table 7. Comparison of Mean TSS values with Effluent Standards (mg/l unless otherwise stated).

Mean TSS Survey Results		**TSS Standards for treated effluent Discharge**				
Fijian Septic tank	**Fijian Secondary Treatment**	**EU**	**WCR**	**Queensland**	**Vic**	**Waikato**
105	112	20	30	30	30 (1) 10 (2)	30
Resort plants complying (mg/l)		N(10), Q(23) , J(12),				
Resort plants not complying (mg/l)		C(53), E(263), I(65), G(71), L(640), K(134), O(32), S(43)				

1- for secondary treatment
2- for new tertiary plants

Table 7 shows that 3 of the 11 secondary plants produced effluent of an acceptable standard in respect of TSS i.e. 30mg/l or less. The Queensland standard for effluent discharges for TSS from a septic tank outlet is 65 to 180 g/m^3 or 65 to 180 mg/l. Of the 5 septic tanks, tested 4 tanks (H,F, M and Q) meet the standard while tank R failed. The Victorian standard for the use of reclaimed water is < 5mg/l for unrestricted use and <30 mg/l for restricted use. The effluent from the complying plants in Table B could be used for restricted use as reclaimed water.

Total Nitrogen

Table 8 shows a comparison of the mean Total – N from the survey compared with effluent discharge standards.

Table 8. Comparison of Mean Total –N values with Effluent Standards (mg/l unless otherwise stated).

Mean Total N Survey Results		Total N Standards for treated effluent Discharge				
Fijian Septic tank	**Fijian Secondary Treatment**	**EU**	**WCR**	**Queensland**	**Vic**	**Jamaica**
85	25	10	10	15	10 (1)	0.081 mg/l^{-1}
Resort plants complying (mg/l)		C(<3), I(<3), N(<3) , J(4),				
Resort plants not complying (mg/l)		E(25), G(20), L(21), K(18), L(640), O(62), Q(34), S(17)				

1- for tertiary treatment

Table 8 shows that 4 of the 11 secondary plants produced effluent of an acceptable standard in respect of Total –N i.e. 10 mg/l or less. The Victorian Standard for Total-N for unrestricted and restricted use of reclaimed water is 5mg/l where there is a risk of runoff into surface water or the marine environment. The effluent from the complying plants in Table C could be used for unrestricted and restricted use as reclaimed water.

Total Phosphorus

The mean values for Total P from the survey are compared with effluent discharge standards in Table 9.

Table 9. Comparison of Mean Total –P values with Effluent Standards (mg/l unless otherwise stated).

Mean Total P Survey Results		Total P Standards for treated effluent Discharge			
Fijian Septic tank	**Fijian Secondary Treatment**	**EU**	**Jamaica**	**Vic**	**Queensland**
14	7	1	0.055 mg/l^{-1}	0.5 (1)	5
Resort Plants complying (mg/l)		I(0.8)			
Resort plants not complying (mg/l)		C(5.9), E(11), G(4.6), L(8.2), K(8.6),N(8.6), O(12), Q(8.8), J(5.4), S(43)			

1 – for tertiary plants

Table 9 shows that only 1 of the 11 secondary plants produced effluent of an acceptable standard in respect of Total –P of 1 mg/l. However if the Queensland (5mg/l) is standard is applied 1 plant (G) would also meet the discharge standard. The Victorian Standard for unrestricted and restricted use of reclaimed water is 0.5mg/l where there is a risk of runoff into surface water or the marine environment. None of the plants achieved this standard.

Faecal Coliform

A comparison of the mean values for faecal coliform numbers and effluent discharge standards can be found in Table 10.

Table 10. Comparison of Mean Faecal Coliform values with Effluent Standards (c/100ml).

Mean Faecal Coliforms Survey Results		Faecal Coliforms Standards for treated effluent Discharge		
Fijian Septic tank	**Fijian Secondary Treatment**	**WCR (1)**	**Jamaica**	**Queensland**
1876238	240542	43 for shell fish gathering 200	200	150 (1)
Resort plants complying (c/100ml)		C(<100), I(92), O(<1),S(,1)		
Resort plants not complying (cl/100ml)		E(610,000), G(790,000), L(330,000), K(3600),N(120,000), Q(3,800), J(240)		

1- for secondary treatment

Table 10 shows that 4 of the 11 secondary plants produced effluent of an acceptable standard in respect of Faecal coliforms (200c/100ml). Plant J was close to meeting the requirement. The WHO standard for the unrestricted use of reclaimed water is < 200 c/100 ml, while the NSW standard for unrestricted use is <100c/100ml. The WHO guideline for restricted is 1000c /100ml. All the complying plants in Table E would meet the standard for unrestricted and restricted use, while plant J would be suitable for restricted use.

Summary

Septic Tanks

The samples of septic tank discharges were all taken from the outlet of the second chamber. The monitoring information shows that 3 of the 5 tanks meet acceptable standards for BOD, and 4 out of 5 meet acceptable standards for TSS. However the effectiveness of the septic tanks cannot be truly assessed without sampling groundwater from an area adjacent to the septic tanks drainage field. As noted in the report there is insufficient information on Fijian soils to determine the required size of a drainage field to ensure removal/uptake of N and P and the permeability to ensure sufficient residence time to kill faecal coliforms.

Secondary Treatment

Table 11. provides a summary of the secondary plants in the study and identifies which plants have met effluent discharge standards.

Table 11. Summary of secondary treatment plants and those which meet effluent discharge standards.

Plant	BOD	TSS	Total N	Total P	Faecal Coliforms	Process Type
C	y		y		y	activated sludge, settlement pond, wetland
E						
I	y		y	y	y	Treated at municipal plant and effluent returned to site
G						
L						
K						
N		y	y			Activated sludge, UV disinfection
O2	y	y			y	Settlement , trickle filter, Enviro flow system
Q2		y				septic tank , settling tank trickle filter
J2	y	y	y		nearly	activated sludge/ wetland
S	y				y	septic tanks, pond

Discussion

Freshwater/Greywater Use and Disposal

Large quantities of freshwater are used by resorts in Fiji but in many areas water is a limited resource. The conservation of water should be a priority without compromising the resorts normal water use activities. The discharge or drainage of freshwater into coastal waters near coral reefs needs to be minimized. Coral reef organisms have a narrow range of salinity tolerance (salinity 33-36, Birkeland 1997).

Greywater (water from laundry, kitchens, showers, sinks, stormwater, pool backwash) within the resort should be reused as much as possible, to minimize the impact of freshwater discharges on the coral reef environment and to conserve freshwater. The reuse of greywater was not practiced at many resorts.

Adequacy of Current Treatment and Disposal Methods

The range of values found in the current study for untreated domestic waste and septic tanks (Table 5) appears reasonably similar to that found for similarly treated wastewater from other locations (Table 12).

Table 12. Average concentrations of various components found in untreated domestic and septic tank wastewater.

BOD mg/L	TSS mg/L	TN mg/L	NH_4 mg/L	NO_3 mg/L	TP mg/L	PO4 mg/L	FC	Reference
Untreated Domestic								
110-400	100-350	20-85	12-50	<1	4-15	3-10		Corbitt 1989
155-286	155-330		4-13	<1	6-12		10^6-10^8	EPA 2002
Septic tank								
132-217	49-161	39-82			11-22		10^5-10^8	EPA 2002

The samples were taken at different times of the day at the various hotels. The amount and character of effluent is likely to be variable during the day (Corbett 1989). For example, generally a peak in sewage waste occurs in the morning after people have arisen and laundry activities may be sporadic. Therefore future studies should perhaps, if time and funding allows, have more in-depth sampling at each hotel.

Table 11 shows that the sewage treatment plants sampled do not meet all effluent discharge standards applied elsewhere in the world. Four of the 11 plants sampled were able to achieve 3 or more of the effluent standards identified. However 4 plants could not achieve any of the standards. The results show there is considerable variation in the performance of the secondary treatment plants particularly with respect to achieving suitable levels of treatment for Total P, Total N and Faecal coliforms.

As noted earlier, the discharge of sewage waste or sewage effluent which is not appropriately treated into coastal water can have major impacts on coastal habitats and on human health. Sewage effluent contains high levels of nutrients such as nitrate and phosphate which may leads to nutrient enrichment, subsequent algal growth and death of coral reefs. The analytical results clearly show that the more advanced treatment systems produced higher quality effluent, particularly those incorporating ponds or wetlands in the final stage of the treatment process.

Comparing the volumes of effluent produced daily, it can be concluded that large resorts that discharge larger volumes of below standard wastewater would be causing more pollution than small resorts of the same standard. A few of the large resorts, however, do treat their wastewater appropriately.

After classifying the resorts surveyed as small, medium, large (Table 3) the standard of treatment in correlation to size of resorts and location was analysed. This was apart from the three large resorts in Nadi and Suva that were connected to sewer lines. Four out of the five small resorts surveyed utilized septic tanks of which the standard of treatment is questionable. Of the resorts that undertook on-site treatment of wastewater, those that had poor standard of treatment (satisfied one or less of the recommended effluent discharge standards) included three large resorts, one medium and one small, those with an average standard of treatment (satisfied at least two of the effluent discharge standards) included a large and a medium resort , and those with a good standard (satisfied three or more of the effluent discharge standards) included three large and one medium resort. On the Coral Coast, a few of the resorts had a good standard of treatment while a few had a poor standard of treatment whilst the smaller resorts used septic tanks. In the Mamanucas it was a similar case however, more resorts had below standard treatment with only two having a good standard of treatment and the smaller resorts used septic tanks.

Septic tanks and basic primary treatment plants do not provide an adequate degree of wastewater treatment to protect coral reefs as nitrogen and phosphorous concentrations remain very high in the effluent (Table 5). Resorts with septic tanks should ensure that they are sited and maintained such that they are effective in minimising leaching of effluent into ground or coastal waters. Regular pumping out of effluent should also be carried out to avoid overflowing. This is normally when sludge and scum accumulations exceed 30% of the tank volume or overflowing has occurred. Commercial systems should typically be pumped at least annually (USEPA, 2002). One resort had unlined (coral rock) septic tanks for their staff quarters. Due to the inadequacy of containment or treatment of waste in these systems, they are not recommended under any circumstances. Septic tanks in general give poor treatment of waste and are only suitable for small resorts.

Unlike the situation in Fiji, the Great Barrier Reef Marine Park area in Australia has imposed strict controls and penalties on the discharge of nitrogen, phosphorus and other parameters to the sea in order to protect their unique and fragile coral reefs (*Australian Government, Great Barrier Reef*

Marine Park Authority Act 1975, and 1993 amendment). If the sewage has received primary, secondary and tertiary treatment (as defined in Table 13 below) the charge is AUS$200.00 per quarter. If the sewage has received primary and secondary treatment only, the charge is AUS$200.00 per quarter plus an amount calculated under the formula:

$$\textbf{Charge} = \textbf{AUS\$1.9} \times \textbf{V} \times (\textbf{N} + \textbf{P})$$

where:

N is the concentration of nitrogen, expressed as milligrams per litre, assessed to be discharged in the quarter (as measured in a accredited laboratory); and

P is the concentration of phosphorus, expressed as milligrams per litre, assessed to be discharged in the quarter (as measured in a accredited laboratory); and

V is the total volume of sewage, expressed in megalitres, discharged in the quarter (sealed meters are installed at all discharges).

Table 13. Standards of secondary and tertiary effluent discharge in the Great Barrier Reef area in Australia *(Source: Australian Government, Great Barrier Reef Marine Park Authority Act 1975 and 1993 amendment).*

BOD mg/L	TSS mg/L	pH	DO mg/L	TN mg/L	TP mg/L	FC Col./100mL
Secondary treatment						
<20	<30	6-8.5	>2			<200[a]
Tertiary treatment						
<20	<30	6-8.5	>2	<4[b]	<1[b]	<200[a]

a. Average E. Coli value in 5 effluent samples, no sample to be above 1000 colonies/100mL.

b. Sewage can fail to comply with regulation if not more than 5% of the annual volume of effluent generated is discharged into the Marine Park by a land-based outfall.

In the current study, the disposal of partially-treated effluent direct to the sea was only encountered in a couple of resorts (E,K) and the quality of effluent is far below the necessary standards in Table 13. Upgrading to advanced treatment incorporating nutrient removal and disinfection for these resorts is necessary.

In the Great Barrier Reef area resorts which dispose on land for irrigation do not have to comply with the regulations shown in Table 13. However, it should be noted that discharge of treated effluent to land, or septic tank leachate to soak pits does not necessarily guarantee protection of the marine ecosystem. There are calcareous sand and rock materials at most of the sites in the present study and the topsoil layer is typically thin. These type of soils will provide little removal of nitrogen and phosphorus in the long-term. Typical calcium-containing United States sands will essentially exhaust their capacity to remove phosphorus in 3-6 months, after which only particulatebased organic phosphorus will be removed (USEPA 2002). Nitrogen removal is usually much poorer than phosphorus (USEPA 2002) as although ammonia is rapidly absorbed by soils, the negatively charged nitrate ion is readily leached into groundwater (ANZECC 2000). Vegetation present will uptake a portion of the nutrients but if the amount of effluent sprayed onto land exceeds the rapid uptake capability of the plants, the nutrients are likely to be washed into the groundwater.

Australia and New Zealand have guidelines for irrigation water concentrations of N and P in order to minimize the risk of contaminating ground and surface water. These guidelines are shown in Table 14. Trigger values indicate concentrations which if above, there is a possible risk of contamination of ground or surface waters. Treated effluent from resorts C, I, J, and N all met most of the standards required for reuse of effluent except for Total P.

Table 14. Australia and New Zealand agricultural irrigation water trigger values (TV) for long term (100 year) and short-term (<20 years) periods (ANZECC 2000).

Element	Long Term TV (mg/L)	Short-term TV (mg/L)
Nitrogen	5	25-125[a]
Phosphorus	0.05	0.8-12[a]

[a]Requires site specific assessment

There is currently a lack of data on the capacity of Fijian soils and vegetation to remove/uptake N and P, and this information is required to make an accurate assessment of trigger values for irrigation water. However, given the sensitivity of coral reefs to increased nutrients and the predicted low removal capacity of the coral/sand type soils, the short-term trigger values of N and P are likely to be at the low end of the range shown in Table 14. Based on observations of algal growth around many resorts which irrigate their land with wastewater, a significant proportion of N and P is probably leaching through into groundwater and out onto the reef flat. Effluent has been shown to travel large distances (400-1600m) in groundwater flowing through the permeable (sand, coral) soils found commonly on the islands and coastal areas (Dillion 1997). The water table is shallow in most of the low-lying island and coastal areas and effluent will not have to travel far to reach it. Once there, it will tend to follow a hydraulic gradient towards the ocean. Therefore it is important that resorts realize that irrigating onto land, while better than direct discharge to the sea, will not necessary guarantee protection of their coastal environment. Nutrient removal prior to irrigation is the best practice solution.

To further minimize any negative impacts on coastal waters from discharge of greywater it is recommended that all resorts shift to use phosphate free products for their laundry and kitchen detergents and room soaps. This simple change should significantly reduce the level of phosphorus in their wastewater since detergents are known to be the main source of phosphorus in wastewater. In addition, chlorine-based products and disinfectants should be minimised as these could also have effects on marine life if released into waterbodies.

Wastewater Management

The majority of resorts in this study indicated that they had undertaken some type of upgrade to their wastewater systems in the last 7 years. In some cases where a new sewage treatment plant of higher treatment level or larger septic tanks were put in this could have led to a big improvement in their wastewater treatment. However where minor maintenance work was carried out it is doubtful if any significant change in the level of wastewater treatment has occurred. While the majority of resorts were satisfied with their wastewater treatment it is concerning that the general level of treatment may not be sufficient to protect coral reefs and the use of the coastal waters for recreation and the harvest of fisheries. This indicates a lack of awareness or will on the part of many of the resorts and wastewater engineers in Fiji to implement the necessary treatment technologies.

Coastal Water Quality

The coastal water quality was not measured in the current study but evidence suggests that nutrient levels are elevated in many areas near resorts (Mosley & Aalbersberg 2003). Regular monitoring of coastal water quality for nutrient levels is recommended but no resorts reported regular monitoring of their coastal water. If coastal water sampling was performed ANZECC (2000) provide trigger values for inshore (coral dominated) marine waters for nutrients and other parameters (Table 15).

Table 15. ANZECC (2000) guidelines for inshore marine waters. Levels above these values may lead to adverse effects on the ecosystem.

TN mg/L	NH_3 mg/L	NO_3 and NO_2 mg/L	TP mg/L	PO_4 mg/L	pH
<0.1	0.001-0.010[a]	0.002-0.008[a]	<0.015	0.005	8-8.4

a. values typical in clear coral reef dominated areas.

Monitoring for bacteria levels is also recommended as high levels of faecal coliforms were found in many of the sewage effluents. The discharge of non-disinfected sewage effluent into the marine environment may result in bacterial contamination of waters and exposed biota. This poses a public health risk (nausea, vomiting, diarrhoea, and ear and throat infections) to tourists which use the waters for recreation and villagers that harvest the fisheries. Guideline levels of organisms which indicate whether coastal water is safe to swim in for Fiji are indicated in Draft Sustinable Development Bill (1996) are not available in Fiji but levels for New Zealand marine waters are shown below in Table 16. In Fiji the potential risk to bathers at resorts needs to be better assessed as does the suitability of the indicator organisms used to detect the risk.

Table 16. Surveillance, alert and action levels for faecal coliforms in marine waters in New Zealand (New Zealand Ministry for health and Ministry for the Environment 2003).

Surveillance/Green Mode: No single sample greater than 140 enterococci/100 mL. Continue routine (e.g. weekly) monitoring.
Alert/Amber Mode: Single sample greater than 140 enterococci/100 mL Increase sampling to daily (initial samples will be used to confirm if a problem exists). Consult relevant authority to assist in identifying possible sources. Undertake a sanitary survey, and identify sources of contamination.
Action/Red Mode: Two consecutive single samples (resample within 24 hours of receiving the first sample results, or as soon as is practicable) greater than 280 enterococci/100 mL. Increase sampling to daily (initial samples will be used to confirm if a problem exists). Consult the CAC to assist in identifying possible sources. Undertake a sanitary survey, and identify sources of contamination. Erect warning signs. Inform public through the media that a public health problem exists.

Table 17. Summary of recommended standards for wastewater and inshore coastal waters

Parameter	Untreated	Discharged to Coral Reef Areas	Used for Irrigation	Inshore Coastal Water Quality
pH		**6-8.5**		**8-8.4**
BOD (mg/L)	**110-400**	**<20**		
TSS (mg/L)	**100-350**	**<30**		
TN (mg/L)	**20-85**	**<4**	**25-125**	**<0.1**
TP (mg/L)	**4-15**	**<1**	**0.8-12**	**<0.015**
Faecal Coliforms (c/100mL)	**10^6-10^8**	**<200**	**<1000**	**<140**
Sources	**Corbitt 1989 EPA 2002**	**Great Barrier Reef Marine Park Authority Act**	**ANZEEC 2000 WHO**	**ANZEEC 2000**

Recommendations

1. Resorts in Fiji should upgrade to an acceptable standard of wastewater treatment (e.g secondary treatment with additional nutrient removal systems such as vegetation beds, wetlands, or nitrification/denitrification units). This is especially urgent for resorts near coral reef areas.
2. All resorts should adopt the use of low- or non-phosphate detergents as they are an easy way to markedly reduce the P content in sewage and laundry wastes. These detergents often have it indicated on the label that they are low or non-phosphate and can be obtained from JohnsonDiversey NZ through Fiji Chemicals Ltd.
3. Resorts should conduct regular monitoring (once a month at minimum) of key waste parameters such as nutrient (phosphorus and nitrogen), faecal coliform, suspended solid and BOD levels to determine their effluent standard which would judge the effectiveness of their treatment systems. This monitoring should be carried out by a recognized laboratory.
4. Further studies collecting waste over a 24 hour period should be conducted for these same key waste parameters for effluent from a sewage treatment plant or going to a municipal sewer, in order to account for variation in the amount and character of effluent throughout the day
5. Resorts should adopt the reuse of greywater to reduce freshwater usage and to minimize volumes of freshwater discharged into coastal waters.
6. The Ministry of Health should adopt appropriate standards for effluent discharges and require resorts to comply. A monitoring programme will need to be instigated to ensure compliance within say 3 to 5 years.
7. No direct discharges of effluent to marine environment should be allowed unless it is demonstrated that a suitable effluent standard can be achieved and that no practical alternative to marine discharge exists.

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Appendix A: Questionnaire Form

Fiji Hotels/Resorts Liquid Waste Survey Questionnaire

Note: Results to this questionnaire will be treated as confidential and individual Hotels/Resorts will not be identified in reporting of results

1. Hotel/Resort Name ....
2. Contact Person ....
3. Mailing Address ....
4. Telephone ....
5. Fax ....

6. Land Tenure of Hotel/Resort (please tick)

Freehold ☐ Crown Land ☐ Native Land ☐

7. Hotel Capacity

A. Total Number of Rooms .... (indicate number of each below)

Single ....
Double ....
Suite ....
Dormitory Beds ....

B. Maximum Person Capacity .... (indicate numbers if possible)

Adults ....
Children ....

C. Average Hotel/Resort Occupancy Rate .... (%)

8. Freshwater Usage

A. Freshwater Source (please tick)

Municipal Water Supply ☐ Spring ☐ Borehole ☐
Rain water collection ☐ River/stream ☐

Other (please specify) ....

B. Approximate volume of freshwater used .... (L or m^3 per day)

C. What is the consumption level for the various uses? (please tick)

	High	*Medium*	*Low*
Showers/Sinks	☐	☐	☐
Toilets	☐	☐	☐
Kitchens	☐	☐	☐
Laundry	☐	☐	☐
Gardens	☐	☐	☐
Pool	☐	☐	☐
Other	☐	☐	☐

If other, please give details ....

9. 'Greywater' Disposal (water from showers, sinks and laundry wash water)

A. Estimate (if possible) the volume of greywater generated per day

.... (L or m^3 per day)

B. Do you reuse your greywater? (e.g use washwater on gardens)

Yes ☐ **No** ☐ (If no, go to Question C)

If yes, please give details how it is used

....

....

If yes, approximately what proportion of greywater is reused? .... %

C. How is your greywater (other than that which is reused) disposed of? (please describe) ....

....

D. Do you use any phosphate-free detergent products?

Yes ☐ **No** ☐

If yes, please give details where they are used and what products are used

....

....

E. Do you discharge any other freshwater (e.g water from roofs) to the ocean?

Yes ☐ **No** ☐

If yes, please give details

....

10. Type of toilet system (please tick)

Freshwater flush ☐ Saltwater flush ☐ Waterless (pit/composting) ☐

Other type (please specify) ....

11. Type of Sewage Treatment (please tick)

☐ **Sewage Treatment Plant System** (e.g. settling pond, trickling filter)

(please go to question 12 and provide further information)

☐ **Other type of treatment system** (e.g. septic tank, compost toilet, pit etc)

(please go to question 13 and provide further information)

☐ **No treatment** (direct discharge to environment) **(please go to question 14b)**

12. Description of Sewage Treatment Plant System (please tick and provide further information below)

Level of treatment

☐ Primary treatment (basic separation/settlement pond system)

☐ Secondary treatment (e.g. activated sludge, trickle filter)

☐ Tertiary treatment (nutrient removal, filtering or disinfection)

List the individual components of your treatment system and its capacity if known?

....

....

....

Where is the final liquid sewage effluent discharged to?

☐ **Sea**

How far from the coastline is effluent discharged? ....metres

Is a diffuser used at the pipe end? ....

Is the quality of the coastal water tested (e.g. nutrients, coliforms)? (if yes, please specify) ....

....

☐ **Land/Wetland**

Specify how and where it is discharged?

....

....

What proportion of sewage effluent is discharged to land? ....%

☐ **Municipal Sewer System**

Where is municipal treatment plant located? ....

☐ **Stored and transported elsewhere**

How and where is it transported? ....

☐ **Other** Please explain…………………………………………………………..

If possible estimate the volume of effluent discharged daily ___________

Where are the solid wastes (i.e. sludge) from your sewage treatment process/toilets disposed?

……………………………………………………………………………………………..

Are any chemicals used in the treatment process?

Yes ☐ **No** ☐ (If yes, please give details)

………

How often is the treatment plant monitored? (please tick)

Hourly ☐ **Daily** ☐ **Weekly** ☐ **Only if problem** ☐

Other (please specify)…………………………………………

Is the treatment plant effluent quality tested? (e.g. for BOD, faecal coliforms)

Yes ☐ **No** ☐ (If yes, please give details)

……………………………………………………………………………………………………

Do you have standards the treated effluent must conform to?

Yes ☐ **No** ☐ **(if yes, please specify)**

………

13. Description of other types of treatment systems (please tick box below for the treatment system and provide further information if applicable)

☐ **Septic Tanks**

Number of septic tanks ……………………………………

Size of septic tanks (L or m^3) ……………………………………

Type of Septic tank (1 or 2 chamber) ……………………………………

Where is effluent/overflow from tank discharged to? ………………………………

Are any post septic tank filters installed (e.g. sand, vegetation beds)?

Yes ☐ No ☐ (if yes, please specify)

……………………………………………………………………………………

How often is sludge from tanks pumped out? …………………………………………

Where is the sludge disposed of? ………………………………………………………

☐ **Composting toilets**

Type of composting toilet ....

Number of toilets ....

How often are toilets emptied/switched? ....

Where is compost material disposed of? ....

☐ **Pit latrines**

Number of latrines ....

Approximate distance of pit from the sea ....metres

How often on average are new toilet pits dug? ....

☐ **Other type of system** (please provide details) ....

....

14. Management Issues

A. Has your waste disposal systems been modified or upgraded in the last 7 years?

Yes ☐ **No** ☐ (if Yes please provide detail on upgrades)

....

....

....

B. Are you happy with your current waste disposal systems and practices?

Yes ☐ **No** ☐ (if No, specify improvements you would like to make)

....

....

C. Are any upgrades planned in the next 5 years?

Yes ☐ No ☐ **(If yes, what upgrades?)**

....

Thank you for your time

Please return the completed questionnaire to: Batiri Thaman
Institute of Applied Sciences, University of the South Pacific, Suva
Phone: 3212969 Fax: 3300373 Email: thaman_b@usp.ac.fj