ISSN 1818-5614

Economics of liquid waste management in Funafuti, Tuvalu

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IWP-Pacific Technical Report (International Waters Project) no. 36

Global Environment Facility

United Nations Development Programme

Pacific Regional Environment Programme

SPREP IRC Cataloguing-in-Publication Data

Lal, Padma

Economics of liquid waste management in Funafuti, Tuvalu / by Padma Lal, Kalesoma Saloa and Falealili Uila. – Apia, Samoa : SPREP, 2006.

vi + 31 p. ; 29 cm.
IWP-Pacific Technical Report (International Waters Project) no. 36

ISBN: 978-982-04-0356-7
ISSN: 1818-5614

1. Waste disposal in the ground – Sewage disposal – Tuvalu. 2. Waste minimization – Tuvalu, 3. Conservation of natural resources – Tuvalu. 4. Underground waste management – Cost effectiveness – Tuvalu. 5. Septic tanks – Waste disposal – Tuvalu. I. Saloa, Kalesoma. II. Uila, Falealili. III. International Waters Project (IWP). IV. Secretariat of the Pacific Regional Environment Programme (SPREP). V. Title. VI. Series.

333.713 7

This report was produced by SPREP's International Waters Project (IWP), which is implementing the Strategic Action Programme for the International Waters of the Pacific Small Island Developing States, with funding from the Global Environment Facility. This study was funded by IWP.

Cover design by SPREP's Publication Unit
Editing and layout: Mark Smaalders
Printed by: Marfleet Printing Co. Ltd., Apia, Samoa

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Acknowledgments

Many people in Tuvalu made it possible to complete this study in the short time available. Dr Stephen Homasi, Deputy Director of the Department of Health was most helpful in answering the many questions we had regarding the link between human waste pollution and human health effects. Ms Nese Conway Mr Tene Laupepa (acting pharmacist), Mr Irata Pulusi (pharmacist), and Kilimasi Setoga (statistician), all of Princess Margaret Hospital, assisted in obtaining relevant unpublished data and information. We wish to also acknowledge the assistance given by Ms Nese Conway (Acting Director of Health), Mr Nikolasi Apinelu, (Acting Director of Fisheries) and Mr Tupulaga Poulasi (Fisheries Officer). Mr Filipo Taulima (Director, Public Works Department), gave us access to their raw data on desalination plant and its operations. Mr Gunter Koepke (Water Resource Officer, PWD), Uatea Salesa (Water Civil Engineer, PWD) and Stanley Iona (plumber, PWD) patiently answered many questions that the research team had. To one and all, we say Fakafetai Lasi.

To the staff of SPREP (Paula Holland, Steve Menzies and Rosanna Galuvao-Ah Ching), the team expresses their appreciation for taking care of all the administrative and logistical matters.

Acronyms

AUD	Australian dollar
AusAID	Australian Agency for International Development
BCA	benefit–cost analysis
IWP	International Waters Project
MDG	Millennium Development Goal
SPREP	Secretariat of the Pacific Regional Environment Programme

Map 1: Location of Tuvalu

Executive summary

Tuvalu faces real challenges in relation to the management of its human wastes (*fekau o tino*). This is despite decades of promotion of the use of water sealed flush toilets and septic tank systems as the most hygienic and safe way to dispose of human wastes. These systems were promoted as an alternative to the use of the beach for human waste disposal.

The Tuvalu Millennium Development Report (Tuvalu 2005) notes with respect to Millennium Development Goal (MDG) 7, Target 10 (regarding access to safe drinking water and basic sanitation) that "Tuvalu is on track to achieve the target for access to sanitation, although progress has been slower in the outer islands than on Funafuti". Ninety two per cent of households have access to basic sanitation, and 97% have access to safe drinking water. These figures are, however, deceptive since these performance assessments do not reflect effectiveness of the facilities used or their suitability to the Tuvalu conditions.[1]

Most households have basic sanitation system, but unfortunately the septic tank based system — the most common form of sanitation in Funafuti — was introduced without regard to the geophysical characteristics of the atoll system.

The Tuvaluan environment is characterised by small coral atoll islands, where the groundwater table is generally within 1–1.3 metres (m) of the surface, and even lower in some parts of Funafuti. Only in limited areas can groundwater be found at depths greater than 2 m. As a result, any pollutants from leaking septic tanks and soak pits can easily move into the groundwater and from the groundwater lens into coastal lagoons. Pollution problems in Funafuti are further exacerbated by poorly constructed septic tanks; during high tides and heavy rains the septic tanks and soakage pits overflow into adjacent areas. Adding to this problem is a lack of an integrated water and sanitation plan for Funafuti and other islands in the country, a lack of monitoring and enforcement, and an absence of coordination and harmonisation of "management" of water and sanitation between national government agencies (Departments of Health, Public Works and Environment) as well as the local government (the *Kaupule*). In addition, there is a rapidly growing population and limited land space, resulting in septic tanks being located too close to each other, to wells, and to homes.

Many human health diseases are caused by pollution of groundwater and coastal lagoons; in addition to causing human suffering, these is also a significant economic cost. Human health costs, including the cost of medicine and human health services, are borne by the national government. There are also costs associated with the preventative measures taken by households, including the cost for rainwater tanks, purchasing bottled water, and desalinated water. Coastal lagoon fisheries are also impacted by pollution from human waste, causing declining catches. This has forced fishermen to go further afield in search of their catch. Such costs are likely to increase if rapid improvements are not made to the waste management system.

A number of different management options have been considered by the government and others, largely from a technical perspective, or from the perspective of water requirements. In many instances, however, they have not considered or compared the economic costs of alternative options, integrating financial and human health concerns as well as the economic costs of scarce water used in flushing toilets.

The key objectives of this project, as a component of the IWP-Tuvalu project, are to:

- determine the economic costs of direct and indirect impacts associated with

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[1] This issue is discussed in detail in the Pacific Islands Regional Millennium Development Goals Report 2004 (SPC 2004), along with specific recommendations for improving monitoring of and reporting on both safe water and improved sanitation, as required for MDG Goal 7.

the current human waste management;

- compare these costs with the economic costs of alternative human waste management options, including considerations of the economic cost of water usage;
- identify practical feasibility factors that may influence the adoption and sustainability of alternative waste management options; and
- make key policy recommendations about liquid waste management in Tuvalu.

The report summarises the economic net benefit associated with each of the alternative options together with some practical feasibility factors associated with them. The report concludes by making key recommendations for consideration by the government and development partners.

Method

A “with and without” benefit–cost analytical framework is used to determine economic costs associated with the current poor liquid waste management and alternative waste management options. To determine direct and indirect costs associated with the current sanitation situation, a model was developed for each of the impacts (on human health, on the consumption of water from alternative sources, and on coastal fisheries). In the absence of robust empirical information, changes in each of the impacts were determined based on the secondary literature and information and opinions supplied by experts working in the respective fields of human health, sanitation and coastal fisheries. However, not all these costs can directly be attributed to poor waste management. To reflect the uncertainty, high, best and low cost estimates are provided.

Price, cost and labour cost data were collected from government departments, local retail market outlets, local suppliers of raw material, and fisheries cooperatives. Where value information was only available for years prior to 2005, annual consumer price index statistics published by the government were used to adjust the economic values to 2005 Australian dollars (AUD). All estimates are given in AUD.

Results

Poor liquid waste management in Funafuti is costing the country almost half a million dollars a year, as summarized in the following table. The human health costs of key water borne diseases directly attributable to liquid waste management accounts for about 80% of this cost, or about AUD 400,000.[2] Health costs are followed in terms of importance by the cost of desalinated water.

Summary table i: Economic cost associated with current human waste management (AUD)

Component	High	Best	Low
Human health	452,630	395,807	284,749
Desalination water	49,961	37,470	12,490
Rain water	44,584	27,020	-
Bottled water	14,676	9,784	4,892
Fisheries	14,190	5,676	2,838
Total economic cost	**576,040**	**475,758**	**304,969**

[2] Note that this figure excludes costs associated with worm infestation. Empirical information on worm infestation was unavailable, although worm infestation is very common, particularly among children under five years of age.

To minimize such costs, urgent action needs to be taken immediately. A number of alternative options are available, including replacing existing septic tank systems, and establishing a centralised reticulated system and ecological sanitation system based on composting toilets. However, feasible options available to the government for improving the sanitation system are constrained by both the availability of financial resources and Tuvalu's unique atoll environment. The choice of alternative systems is further constrained by the fact that Tuvalu experiences dry weather for up to 3–4 months of the year, as well as extended periods of drought. In addition, when the rainy season and king tides coincide, much of the land area is subject to regular flooding.

Given the limited financing and physical environment, an ecological sanitation system based on the composting toilet is the only option that is both economically viable and does not rely on water availability (as summarised in Table ii).

Conclusion

Based on economic and environmental considerations, and using economic net benefits as the criteria for selection, the order of preference of technology, as summarized in Table iii, is as follows:

- Compost toilets — new
- Compost toilets — add on
- Replace leaking septic tanks with plastic tanks (unviable)
- Replace septic tanks — concrete tank (unviable)
- Hybrid (plus septic) (unviable)
- Mini treatment system (unviable)

If all Funafuti residents were to convert to compost toilets, Tuvalu could expect to generate net benefits of approximately AUD 2 million each year, as compared with incurring at least a cost of approximately AUD 100,000 annually under other options.

The social acceptability of the compost system is, however, uncertain.

Trials with compost toilets in Tuvalu and elsewhere in the Pacific, such as Kiribati, have demonstrated that although such a system is technologically feasible, locals are reluctant to embrace them for social reasons. The main obstacles include the "newness" of the technology, personal attitudes and preferences. Some have argued that the flush toilet system took almost 20 years to be accepted. The rate of adoption no doubt increased once flush toilets took on a prestige value and were found to offer convenience, comfort and privacy, and once the toilets became incorporated in the house.

The use of compost toilets is seen as a step backwards, particularly because the early designs placed the toilets outside the house. Although later compost toilet designs incorporate these as an integral part of a home, they are likely to be slow to gain acceptance, even if they were to offer health as well as economic benefits.

Another reason for limited social acceptability could be the concerns about human health effects, particularly from handling composted material. While no local trials have been carried out regarding the survival of pathogens in composted material, studies from Kirimati atoll in Kiribati suggest that within six months of composting, there is no evidence of common pathogens, such as eggs of whipworm, Giardia cysts, faecal coliform, faecal streptococci, shigella, and salmonella bacteria (Crennan et al 2002). The risk of diseases from handling composting material is likely to be very low, and certainly lower than the risk of diseases from the current situation.

Summary table ii: Economic costs of alternative household-based human waste management systems (AUD)

Costs or savings	New septic-based toilet	Fix existing septic system	Plastic septic	Composting (add-on)	Composting (new)	Hybrid	Hybrid + fix septic	Mini treatment
Fixed cost per unit	4,200	4,000	3,600	5,200	4,000	4,200	8,200	150,000
Operating cost per unit per year	240	240	240	25	25	50	290	400
Annualised costs per household	924	891	826	871	676	734	1625	18,019
Water saving per household				2,839	2,839			
Annual compost value per household				21	21			

Summary table iii: Funafuti's aggregate economic net benefit associated with each liquid waste management option (AUD)

Sanitation options	Initial capital establishment investment	Annualised cost	Water savings	Compost soil benefits	Annualised option's net benefit (loss)	Health, preventative and environmental benefits (costs)	Total net economic benefit (loss)
Do nothing option						(475,758)	(475,758)
New septic tank	2,683,800	590,136			(590,136)	475,758	(114,378)
Fix septic tank	2,556,000	569,337			(569,337)	475,758	(93,579)
Plastic septic tanks	2,300,400	527,740			(527,740)	475,758	(51,982)
Compost (add-on)	3,322,800	556,745	1,814,363	52,467	1,310,084	475,758	1,785,842
Compost (new)	2,556,000	431,952	1,814,363	52,467	1,434,878	475,758	1,910,635
Hybrid + septic	5,239,800	1,038,063	27,215		(1,010,848)	475,758	(535,090)
Mini-treatment	23,962,500	11,514,105			(11,514,105)	475,758	(11,038,347)

Recommendations

To encourage the adoption of composting toilets, a multi-pronged and sequenced program is needed that incorporates the following:

1. A massive education program highlighting the merits of using composting toilets vs. other management options, including the no action option. Economic values estimated in this study could help provide more focussed and objective quantitative information that can demonstrate the economic costs of the current system as compared with the expected net benefits of changing over to the alternative system, including the savings in freshwater.
2. Development of an integrated liquid waste management plan, involving key stakeholders including the Department of Public Work, Local Kaupule, Department of Environment and the Ministry of Health. The liquid waste management strategy must be linked to the national budgetary process through the national sustainable development strategy, or the Kakega II.
    a. *Institutional reforms*: In the outcome-focussed plan, it is imperative to establish an interdisciplinary waste management task force, and clearly define the roles and responsibilities of each government organisation involved in waste management, while emphasising the shared responsibility for the management of liquid wastes in Tuvalu. Each agency must be adequately resourced and their program of work coordinated and harmonised.
    b. *Economic instruments*: Adopt economic incentives, such as subsidies, to bring about behaviour change.
    c. *Legislative instrument*: Develop appropriate liquid waste management legislation in which composting toilet system are made mandatory in the design and construction of all new homes, and new additions to existing homes. The cost of doing so could be subsidised by the government. An effective monitoring and enforcement system would also be needed.
3. The government could approach a development partner to assist with conversion of the existing septic system with composting toilets for households that show commitment to the use of an ecological sanitation system. The government could also consider approaching development partners for assistance under the Clean Development Mechanism of the Kyoto Protocol.

In conclusion, Funafuti has very few choices available to it with respect to its management of human wastes. If the country does not tackle this issue urgently, the problem is likely to become more acute as population increases, and the predicted climate change-related impacts become a reality.

1 Introduction

Human waste management is a major concern in Tuvalu despite decades of promotion of the use of water-seal flush toilets and septic tank systems as the safest and most hygienic way to dispose of human wastes. These systems were promoted as an alternative to the use of the beach for human waste disposal. Unfortunately, the septic tank-based system was introduced in Tuvalu and many other atolls in the Pacific Islands region without regard to the geophysical characteristics of atolls.

As Franceys et al. note (1992), the choice and design of sanitation systems should take into account the following factors, among others:

1. Soil type, porosity and particle size, which affects the infiltration rate. Sand, rocks and coral rubble have large pores and are inert substances, through which water can readily drain and filter.
2. The groundwater level, or depth at which groundwater is found.

All islands in Tuvalu are coral atolls, featuring continuous eroded reef platforms surrounding a central lagoon (Mclean and Hosking 1992), with a substrate consisting of coral rubble and course sand. All the islands are low lying, with an average elevation of 3 metres (m) above sea level. The groundwater table is just 1–1.3 m below the surface, and is even shallower in some parts of Funafuti. Only in limited areas can groundwater can be found at depths greater than 2 m (Falkland 1999). As a result, any surface pollutants or pollutants from leaking underground septic pits easily moves into the groundwater, and from the groundwater system into lagoons. The pollution problem is further exacerbated by poorly constructed septic tanks; during high tides and heavy rains this results in soakage pits overflowing into adjacent areas (Figures 1A-D). The increasing urban population and limited land space are resulting in septic tanks being located too close to each other, too close to wells, and to homes (Crennan and Berry 2002).

Septic systems in atoll environments (such as Funafuti) do not provide the necessary basic treatment of raw sewage; instead, septic-based sanitation systems in Tuvalu and other atolls in the region become the main source of groundwater and lagoon pollution. As a consequence, communities are unable to use groundwater as a safe source of drinking water. Contaminated drinking and lagoon water also increases the incidence of waste-related human diseases, such as diarrhoea, dysentery, hepatitis, and skin diseases (Fig. 2); these problems are found in Tuvalu (Dr Stephen Homais, Deputy Director of Health, Tuvalu, pers comm., February 2005) and in many other Pacific Island countries (Falkland 2002). Poor human waste management also increases levels of organic matter, nitrates and phosphates in the lagoons, causing eutrophication, changes in coastal ecosystems, and altering the composition and quantity of coastal fisheries catches. Fish poisoning can also result. Some of the health and environmental impacts are caused in part by pollution from animal wastes, particularly pig wastes, which must also be appropriately managed.

Such effects are a source of a real concern to the people of Funafuti, but sanitation remains a low priority in Tuvalu, as is true in most Pacific Islands countries. Sanitation has a low status in local communities, with discussion of the subject often constrained by cultural taboos. In addition, the link between wastes and human health and other impacts is not widely understood by villagers.

To address sanitation issues arising from human wastes, many different waste management systems have been considered or implemented in Tuvalu over the past 15 years. These include fixing the septic tanks and individual household composting toilet trials under the AusAID Waste Management Project. In addition to individual household-based human waste management strategies, there is also the option of establishing mini-treatment plants, a central reticulation system or hybrid toilet system (Crennan 2004). Many of the options, however, have largely been considered from technical or scientific perspectives (see, for example, Falkland 1999), with little consideration of their relative cost or other feasibility issues.

Figure 1a: Regular flooding and poorly designed septic system are major sources of human health and environmental concerns in Tuvalu (Government Housing, Vaifou settlement)

Figure 1B: Flooding inside a house after heavy rains

Figure 1C: Poorly designed and installed septic tank

Figure 1D: Poorly maintained tanks (not cleaned until blocked)

International Waters Project–Tuvalu

The International Waters Project (IWP) aims to strengthen the management and conservation of marine, coastal and freshwater resources in the Pacific Islands region. It is financed through the International Waters Programme of the Global Environment Facility, implemented by the United Nations Development Programme, and executed by the Secretariat of the Pacific Regional Environment Programme (SPREP), in conjunction with the governments of the 14 participating independent Pacific Island countries.

IWP is intended to address the root causes of degradation in Pacific Island waters. IWP–Tuvalu began to address human sanitation issues in 2002. Adopting a community-based approach, the National Coordinator — under the guidance of the National Task Force and working with the local communities of Alapi and Senala — undertook to identify low cost solutions to address waste problems. To identify management solutions, the task force first assessed the root causes of the sanitation problem. It noted that the root causes included a lack of institutional mechanism for waste water management, a poor understanding of the impacts of waste water on the environment and human health, and a poor understanding of the island's geology and water resources.

Following some base line assessments and the identification of root causes, IWP decided to focus on increasing local awareness of the sanitation problems facing the country. IWP conducted a short-term communication campaign to raise awareness of the urgency of sanitation-related issues, and community training workshops to help communities compare a range of practices and technologies (such as using the beach for defecation, upgrading existing septic tank systems, and installing composting toilets and using composted animal and human wastes as soil improver). The project also instituted community-run groundwater monitoring.

Much of the focus of these awareness sessions was on the technical aspects of the alternative management options. While education and communication projects such as these are useful in raising awareness, alone they may not necessarily lead to appropriate decisions and changed behaviour on the part of individuals or governments, because of a lack of incentives for such change to occur.

To support change among key actors and decision makers it is important to develop a better understanding of the incentives (including financial and economic factors) influencing decision making. Economic benefits and costs can provide a powerful incentive for decision makers, and economic analysis can play an important role underpinning their decisions (Lal 2003; Lal 2004).

Economic benefit–cost analysis (BCA) can help identify the economic costs associated with the current (poor) state of human waste management and compare these with the net benefits of alternative options. Economic analysis can help decision makers to make informed choices between different options (Perkins 1994; Sinden and Thampapillai 1995).

The key objectives of this project, as a component of the IWP–Tuvalu project, are to:

- determine economic costs of direct and indirect impacts associated with the current human waste management;
- compare these costs with the economic costs of alternative human waste management options, including considerations of the economic cost of water use;
- identify practical feasibility factors that may influence the adoption and sustainability of alternative waste management options; and
- make key policy recommendations about liquid waste management in Tuvalu.

2 Overview of human waste management in Tuvalu

Funafuti residents annually generate about 475 tonnes of human faeces, *fekau o tino*, which is disposed of using one of several methods (see Box 1). According to the 2002 Census Report (Government of Tuvalu 2002), 92 per cent of households use either flush toilets linked to septic tanks or pour toilets linked to pit toilets. Only 8 per cent of households do not have access to 'improved' sanitation system (Table 1).

Table 1: Distribution of toilet type by island

Island	Flush and septic toilets	Pour toilets	None	Total
Nanumea	31	75	22	128
Nanumaga	5	103	11	119
Niutao	11	81	51	143
Nui	9	84	15	108
Vaitupu	101	92	41	237*
Nukufetau	22	82	14	118
Funafuti	424	163	43	639*
Nukulaelae	26	39	3	68
Niulakita	5	3	0	8
Total	634	722	212	1568

* Includes nine composting toilets on trial. Source: Government of Tuvalu 2002.

The MDG report (Tuvalu 2005) noted that Tuvalu is on track in relation to MDG goal 7 and indicators 30 and 31: "sustainable access to improved water source" and "sustainable access to improved sanitation" respectively (see Table 2 and Box 2).

Table 2: Progress in Tuvalu in meeting Millennium Development Goal targets

Indicator	Tuvalu baseline (1991)	Most recent status (2002)	MDG target (2015)
Proportion of households with sustainable access to an improved water source, urban and rural	National 90% Funafuti 93% Outer islands 98%	National 93% Funafuti 94% Outer islands 98%	95% 97% 99%
Proportion of households with sustainable access to improved sanitation, urban and rural	National 77% Funafuti 84% Outer islands 74%	National 87% Funafuti 92% Outer islands 83%	89% 92% 87%

Source: Tuvalu Millennium Development Goal Report 2004 (see Tuvalu 2005)

These figures are deceptive, however, because the performance assessment against the Millennium Development Goals was carried out only in terms of "access" to sanitation facilities. This indicator does not reflect the effectiveness of the facilities used or their suitability to Tuvalu conditions. As mentioned earlier, the Tuvalu environment comprises coral atoll islands and high groundwater levels, and it is subject to regular flooding, particularly in times of heavy rains and or king tides. The septic tanks are often poorly designed despite the presence of specific building codes and design specifications, including the capacity of septic tanks and the design of soak pits and toilet structures, etc. The building codes are not enforced, largely because the codes, which were developed in early 1990s, have not yet been approved. Thus it has been found that poorly constructed septic tanks, together with unique flooding potential, also are responsible for the current ineffective septic system, causing moderate to high pollution of groundwater and the lagoon (Table 3).

Box 1: Current human waste management systems in Tuvalu

Pour flush latrines (water sealed latrines)

The water sealed latrine is a modified pit latrine that uses a water sealed toilet pan to stop the smell from the pit coming back up the toilet pan. The pit is not totally sealed, so the waste water leaks directly into the ground. It uses any type of water, even water from the laundry or bathroom. Main components of a pour flush toilet are: water sealed pan supported by concrete; a pit, which is a hole in the ground, supported by stacks of stones around the pit to stop soil from entering the pit; a concrete slab to separate the pit from the pan; and a hut. In Tuvalu pour flush toilets are usually separated from the main house, so a small hut is usually built to shelter the toilet. This technology is unsuitable for an environment such as Tuvalu because of high groundwater levels, which rise even higher during king tides, and regular flooding after heavy rain.

Septic tank systems (flush toilets)

A septic tank system has three major components: a flush toilet, a septic tank and a soak pit. All three need to work properly if the desired level of treatment is to be achieved. The system relies on water, and the system needs to be flushed with fresh water for good bacteria to break down the organic matters in the septic tank. The septic tank needs to be sealed properly so it is water-tight, meaning no leaking from the tank to the outside environment and vise versa. The septic tank is connected to a soak pit that works as a nutrient filter and drying bed. Its purpose is to filter and prevent nutrients and other solids from entering the groundwater. The soak pit also filters any water-borne bacteria from getting into the groundwater.

In the design of the septic tank system a number of key design principles must be met:

- Sufficient retention time must be allowed for the solids in the sewage to separate from the liquid and, after this separation, time must be allowed for the liquid to stabilise.
- Layout of pipes must provide for quiescent hydraulic conditions for efficient settlement of solids.
- The septic tank must be large enough to meet the needs of the family.
- The design must ensure no leaks or blockages occur in the system.

Furthermore, septic tanks must be regularly emptied (at least once each three years) to prevent the tanks from overflowing.

Aerated mini-treatment plant

This system is currently in use in the Government Building. Three to four houses are normally connected in such a system, and the toilet piped to a mini-treatment plant. In the treatment plant, solids are separated from the liquids. The treated solid waste is used for composting, while the nutrient-rich liquid effluent is sprinkled on grass (Filipo Taulima, pers. comm., Nov 2005).

Source: Franceys, Pickford and Reed 1992

Other problems include that fact that the level between tank outlets and effluent disposal areas is not considered during the construction of septic tanks. Furthermore, septic tanks are not regularly cleaned of septage. People typically consider cleaning only when the septic tank is blocked (Fig 1D). Furthermore, there is no organised cleaning service available in the country and people have to rely on privately hired plumbers for removing septage from the septic tanks. These services, too, rely on manual labourers emptying and resealing the tanks. Only government houses are cleaned by the Department of Public Works.

Further compounding the pollution problem is the shortage of water for toilet flushing. Funafuti regularly faces water shortages, which result in 80–90 per cent of households resorting to defecating on coastal beaches during periods of drought. In some cases during droughts, households use sea water for flushing the toilets, which further upsets the chemistry of septic tanks, and which results in a change in the types of bacteria in the septage. Consequently, incompletely digested or untreated effluents seep out of the septic system and ultimately enter the groundwater.

Table 3: Weaknesses in current waste water treatment system	
Audited septic tanks lacked required inlet and outlet fixture	96%
Audited septic tanks had hydraulic capacity smaller than required for family size	48%
Audited septic tank systems discharged into small diametre soak holes rather than absorption or evapotranspiration areas.*	30%
Residents complained about septic tank problems	27%
Residents complained about septic tank overflow or wet ground	23%

* Discharge into these soak holes represent a moderate to high groundwater pollution risk.

Source: Septic Tank Audit Report (2001) prepared under the AusAID Waste Management Project, Funafuti.

Box 2: Assessing water and sanitation via the Millennium Development Goals (MDGs)

MDG Indicator 30 monitors access to improved water sources, based on the assumption that improved sources are likely to provide safe water; “unsafe” water is the direct cause of many diseases in developing countries. Access to safe water refers to the percentage of the population with reasonable access to an adequate supply of safe water in their dwelling or within a convenient distance of their dwelling. The Global Water Supply and Assessment Report 2000 (WHO/UNICEF 2000) defines reasonable access as “the availability of 20 litres per capita per day at a distance no longer than 1,000 metres”. However, access and volume of drinking water are difficult to measure and so sources of drinking water that are thought to provide safe and reliable supply of water are used as a proxy. Data on improved water sources is collected through census questions; in Tuvalu improved water sources are defined as including tanks, cisterns, or tank and cisterns; unimproved sources include wells, community cisterns, and communal taps.

MDG Indicator 31 is intended to measure the proportion of the population with access to facilities that hygienically separate human excreta from human, animal and insect contact. Facilities such as sewers or septic tanks, pour-flush latrines and simple pit or ventilated improved pit latrines are assumed by WHO and UNICEF to be adequate, provided that they are not public. In Tuvalu flush toilets, pour flush toilets, and water seal toilets are all defined as constituting “improved” sanitation (i.e. safe from a human health standpoint). The intent behind Indicator 31 is reduction of health problems associated with improper disposal of human waste. While various types of pit toilets, septic systems and cesspools can serve this function in many environments, on atolls and small islands pit toilets can cause direct contamination of groundwater found in basal aquifers. Ironically composting toilets, which have a much lower likelihood of contaminating the groundwater aquifer, would be classified as “other” in the Tuvalu census, and would be considered unimproved.

Source: Pacific Islands Regional Millennium Development Goals Report 2004 (SPC 2004).

Institutional management

In Tuvalu, no one government agency has the responsibility for managing human waste (this is the case most jurisdictions worldwide). The Public Works Department has a role in the cleaning of septic tanks, but has not had the resources to provide the appropriate level of services required. The Department of Health primarily addresses human health problems. More recently the Kaupule has introduced by-laws mandating that each household have a toilet facility and prescribing its actual location in the house. However, the design of the toilet system is not regulated.

The Public Works Department recently developed a draft set of building codes but these have not yet been approved. Environmental management falls under the responsibility of the Department of Environment, but there is no environmental management plan or legislation guiding its activities. There is also no national water and sanitation plan or strategy, although water has always been considered to be a high-priority issue in the country’s national plans (Kakega I and Kakega II).

There has been little or no collaboration between the responsible agencies until recently. The establishment of the Waste Management Project in 2000 and IWP in 2002 has changed this, and there is now a greater degree of information sharing and coordination of liquid waste management efforts. The establishment of the IWP National Task Force has also helped increase the profile of liquid waste management problems in the country.

Impacts

Poor sanitation conditions have direct and indirect impacts on the environment, including the pollution of groundwater and the coastal ecosystem, and human health (Fig. 2a and 2b, Fig. 3). These all have economic costs. Some of these costs are borne directly or indirectly by individuals, although people often do not directly associate their actions with the impacts they suffer. A large portion of the costs are actually borne by the Government of Tuvalu, particularly because medical services are provided at no cost to patients. What is the magnitude of the economic costs of such impacts associated with poor waste management? What other options may be economically, environmentally and socially more viable?

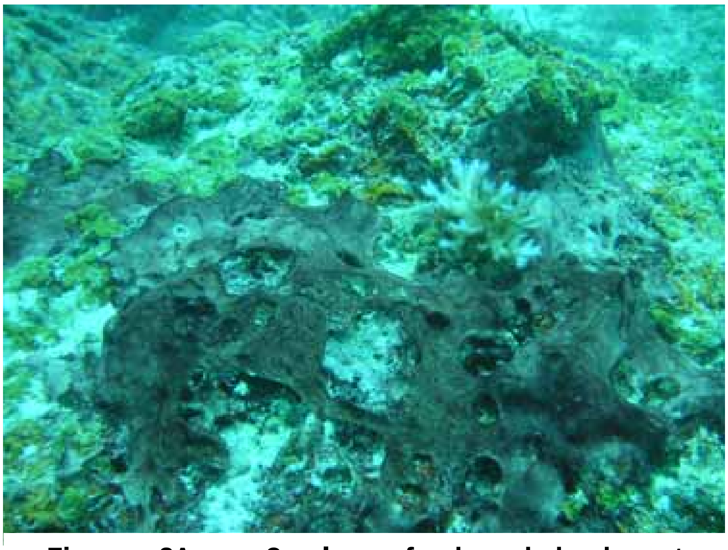

Figure 2A: Coral reef degraded due to eutrophication caused by poorly treated human waste discharge

Figure 2B: Healthy coral reef ecosystem

Figure 3: Child with serious boils and skin infections

3 Economic analysis—methodology

To estimate the economic costs and benefits of the current sanitation system and to compare these with the economics of alternative management options requires an economic analysis.

Economic analysis takes a national (social) perspective in which all costs — direct and indirect, as well as ecological and environmental aesthetic costs, either paid for or not — are explicitly considered. The estimated economic benefits (minus the economic costs of improved management) are used to compare the two alternative management scenarios. When costs and benefits flow over time, the appropriate measure for comparison is the net present value of the two activities, or an annualised cost of the flow of costs.

Financial analysis focuses on the financial interests of individuals, families and/or the community directly affected by an activity. It comprises considerations of the monetary costs of all effects, either paid for or not. For an individual, when comparing the desirability of improved waste management over the existing situation, improvements will make sense if the current health costs (plus any ameliorative costs) are less than the expected costs under the alternative scenario of management. In Tuvalu, however, as discussed later, the government pays all medical costs and provides desalinated water at a highly subsidised rate (30 per cent of the actual cost); therefore, the financial cost to each individual household is minimal.

Given that the benefits derived from improved waste management in Tuvalu take the form of public goods, individual households would generally have little incentive to change their current system of human waste disposal. Thus financial analysis is not an appropriate methodology to use in this study, where the key question is: “should the government consider introducing an alternative human waste management system for Tuvalu?”

Benefit–cost analysis

Benefit–cost analysis (BCA) is the appropriate analytical economic framework to help identify the most appropriate human waste management option. It is based on a “with-and-without” analysis of management options. BCA involves comparing the net economic benefits of the current situation of liquid waste management (referred to in this document as the “without” scenario) with the net economic benefits of the alternative strategy of improved waste management (i.e. the “ with” or improved management scenario).

The benefit of producing human wastes is individual survival, which will be the same with or without waste management, although life expectancy may be adversely affected by poor waste management. The net benefits of waste management are the economic value of the reduction in negative impacts of human wastes on human health, fisheries, and the environment, and the economic value of the preventative measures taken by individual households to avoid or minimize negative waste impacts.

The basis of comparison between “with” and “without” management is thus the net economic cost savings that society expects to make by improving human waste management. When comparing alternative options, the option that generates the highest economic cost savings (including environmental and human health cost savings) would in ideal situations be the preferred choice.

Often, not all costs and benefits of a management option can be quantified, which may necessitate that a decision be made on the basis of incomplete information. To guide such decision making, a sensitivity analysis, which involves considering a range of values, is useful.

BCA assumes that all other institutional and market conditions prevail. Such an assumption cannot be made in most developing countries. Consequently, operational or feasibility factors may also become important determinants of the success of the preferred choice. Such feasibility factors include availability of funds, regular access to electricity and water supplies, and the capacity of the local populace to maintain any equipment. None of these issues are addressed in the report. In this study, both the economic net cost savings of each option are identified and the relevant feasibility factors.

With-and-without cost estimation

In the "without" scenario, direct economic costs of wastes include costs associated with human health effects, including hospital costs, costs of private doctors' fees, medicine, the value of human life in the event of deaths, and the cost of human suffering. It also includes the loss in potential earnings from not composting, and indirect costs of the loss in coastal fisheries and changes in ecosystems (Table 4). In the "with" management scenario the costs associated with the same impacts are also assessed. The difference between the with and without scenarios is the net economic benefit associated with the option.

Table 4: Typology of costs considered under "with" and "without" management scenario

Without: Economic costs of current waste management approach	**With:** Economic costs with improved waste management, assumes negligible or zero impact from waste
Direct costs:	
• treatment of diarrhoea, dengue and skin diseases, including transportation costs to the hospital or private doctors, doctors' fees, if any, and the cost of medicine	• no loss of human lives
• financial costs of health services borne by the government	• nil government expenditure on waste related illnesses
• economic value of loss of human life attributable to waste	• loss of human life and human suffering avoided
• economic cost of human suffering	
• private costs associated with preventative measures—cost of rainwater tanks, filters and bottled water	• nil private costs
• costs of the government's preventative actions	• no preventative measures needed • no desalination of water needed
• potential economic value of composted organic matter	
Indirect costs:	
• economic value of the loss in fisheries	• loss of fisheries and environment avoided

The economic cost associated with the "with management" option is the sum of the costs avoided:

- health costs (C_{skin}+ $C_{diahorrea}$ + $C_{boils, sores}$, etc.)
- economic cost of human life ($C_{human\ life}$)
- preventative costs ($C_{desalination}$ + $C_{rainwater}$ + $C_{bottled}$)
- cost to fisheries ($C_{fisheries}$)
- foregone earnings from human waste not composted ($C_{composting}$).

To determine the economic cost of wastes, it was first important to determine the causal relationship between wastes and their impacts on human health, tourism, fisheries and the environment. This was done using secondary literature and expert advice. Market values were then assigned to these impacts using one or more of several methods (Box 3) and data from different sources was collected using mixed methodology, as summarized in Appendix A.

Box 3: Market and Non-market valuation techniques used in this study

Loss in production

This method measures the loss of marketable production due to the effects of pollution from liquid wastes. The loss of coastal fisheries due to pollution and eutrophication could thus be measured using the loss in production method. Market prices and quantities are used to estimate the impact of wastes on the coastal fisheries in Funafuti, assuming direct causal relationships are known.

Foregone earnings

Sewage material that is not composted and used as soil in a country such as Tuvalu, where topsoil is a scarce commodity, is a wasted resource. The foregone earnings method involves estimating the economic value of composted wastes (which communities could sold, thus generating earnings). Ideally, the foregone earnings equal the total local value of the composted material.

Preventative and mitigatory expenditure

This technique involves using costs incurred by households to prevent household members from becoming sick due to drinking contaminated water as a proxy for the cost associated with polluted water due to waste contamination. Similarly, households use rainwater and or desalinated water instead of groundwater because of concerns about the polluted nature of groundwater. The annualised cost of producing desalinated water, for example, is used as a proxy for the waste-related cost of polluted water that is avoided. Similarly, the annualised cost of a rainwater tank is considered as the proxy cost of rainwater substitution.

Other methods (not used in this study)

Non-market valuation

A number of different non-market techniques are often used to estimate economic values of goods and services that are not directly bought and sold. These techniques include revealed preferences methods, such as travel costs and hedonic pricing, and expressed preferences, such as the contingent valuation method and choice modelling. Of these, the contingent valuation method is most appropriate for determining the environmental value associated with wastes (see Freeman (1993) and Carson (2003) for details on the different methods).

Contingent valuation

This method relies on people's ability to express their willingness to pay for an improved environment amenity through proper human waste management. In this method, people are directly asked to express their values for a "clean" environment. This can be done using open-ended questions such as, "How much are you willing to pay for a specified increment in environmental improvement?" Alternatively, people can be asked discrete questions about whether they are willing to pay a specified amount and mathematically arriving at an average willingness to pay estimate for the good.

Non-market valuation was not used in this study because the household activities were largely subsistence based, or were based on remittances from Tuvaluans living abroad. Asking hypothetical questions about willingness to pay for improvements was judged to be unsuitable in such an environment, where market concepts are poorly understood (Freeman 1993; Carson 2003).

In this study, the economic costs associated with the current waste management system are compared with the economic costs associated with alternative management systems: fixing existing septic tanks, establishing composting toilets as an add-on to existing houses, establishing composting toilets when a new house is constructed, installing hybrid flush toilets with vacuum pumps (in conjunction with repaired septic tanks), and mini-reticulated systems.

Previously, economic analysis was conducted on the effect of waste on human health, and the environment was defined for each management system.

Feasibility assessment

To identify key feasibility factors, past waste management projects in Tuvalu and elsewhere in the Pacific were analysed to identify factors that may have contributed to their success or lack of success. The feasibility factors considered included social, cultural and other conditions that were found to be important determinants of the adoption and maintenance of the management solution. The Tuvalu projects reviewed comprised the following:

- the liquid waste management component of the AusAID/Government of

Tuvalu Waste Management Project;

- the imported plastic septic tank system installed by the Department of Public Works at some government houses; and
- the sea water-based reticulated system recommended by the Asian Development Bank (ADB) study.

Data collection

For waste impact analyses, data was gathered using different approaches and methodologies. This study is based on primary and secondary data collected from several different sources. A mixed methodology was used to suit both the interviewee and the nature of the information. Structured, semi-structured, and open-ended interview formats were used to elicit information, but the process was guided by written questionnaires. The national level qualitative and quantitative information was collected from various government stakeholders (e.g. the Departments of Health, Public Works and Environment and the Ministry of Fisheries (see Appendix A).

Financial costs and price information were obtained from local suppliers (bottled water, rainwater tanks, trucks and tanks used for septage clean up) and the Public Works Department, and cost estimates were obtained from the AusAID Waste Management Project and the Ministry of Health. Where price data was available from previous years, these were adjusted to 2005 values by using the consumer price index indices recorded in the Tuvalu Census and the Tuvalu National Sustainable Development Plan, Te Kakega II.

Using the results of these interviews and data collected from other sources, typical impact models associated with wastewater effects were constructed for a typical household. These models were then used to assess the economic costs of different categories of impacts of wastewater on human health, fisheries and the coastal ecosystem.

In Tuvalu, specific information about the effects of poor human waste management on human health, groundwater and coastal ecosystems is limited and, in some cases, almost non-existent. Impact models based on the Delphi method were derived, in which expert knowledge of specialists working in their respective fields were used to determine the nature of the influence of waste-related human health impacts on likely changes in the use of desalination water and rainwater. In the case of coastal fisheries, the "benefits transfer" method was used in the absence of local empirical data to determine the likely quantitative impact on local fisheries output. Because there is a level of uncertainty associated with each of the data sets, sensitivity analysis was also carried out giving low, best and high estimates for proportionate changes in each of the key parameters due to improvements in sanitation. These assumptions are summarised in Table 5.

Table 5: Attribution factor used in this study regarding the effects of poor sanitation on human health, groundwater and bottled and desalinated water use, and coastal fisheries (%)

	High	Best	Low
Human Health[a]			
Conjunctivitis	30	20	10
Diarrhoea	80	60	50
Septic wounds/sores	90	70	60
Boils	90	70	60
Fungal infections	90	70	60
Skin rash	90	70	60
Ringworm	80	60	50
Dhani/tinea	90	60	50
Helminth and other worms	na	na	na
Alternative water sources[b]			
Desalinated water	40	30	10
Bottled water[c]	30	20	15
Rainwater tanks[c]	33	20	0
Fisheries[d]	10	4	2

Sources: a: Dr Stephen Homasi, Acting Director, Department of Health, pers. comm. November 2005); b: Filipo Taulima, Director, Department of Public Works, pers. comm., Nov 2005; c: Based on personal opinion of Kelesoma Saloa, IWP Coordinator, SPREP, Funafuti; d: Based on Tonga experience (see Lal and Takau 2006).

4 Economic costs of poor sanitation

The economic costs of poor sanitation include (i) costs associated with treating human health effects caused by water-borne pathogens, including (a) hospital overhead costs, and (b) preventative costs of using desalinated water, rainwater, and bottled water, and (ii) the costs of declines in coastal fisheries attributable to human wastes.

Human health effects

Limited water quality assessments carried out in June and December 2005 suggest that groundwater in Tuvalu is highly contaminated with faecal matter. In June 2005, for example, the groundwater and lagoon water bacterial count was significantly greater than that which was recorded for the "control (a rainwater tank; see Table 6). Nutrient levels (nitrites, nitrates and phosphates) varied little between different sites, which may be due in part to the coarseness of the testing method used; nutrient tests were carried out using nutrient test strips (Nitrate and Nitrite Test Strip, SENSAFE, USA).

Table 6: Water quality assessment, June 2005

Water source	Bacterial count	Nitrites	Nitrates	Phosphates
Groundwater (north of Luck set)	>130	0	0	<10
Lagoon water (old jetty)	>62	0	0	<10
Rainwater tank (control—Tausoa Lima, southern tank)	<50	5	0	<10

Source: Water Quality Report, June 2005, Waste Management Unit, Department of Environment, Government of Tuvalu, Funafuti

The link between faecal contamination of water and human diseases is well recorded (Crennan and Berry 2002; Falkland 2002). Water-borne diseases directly linked to poor sanitation include diarrhoea, dysentery and other gastroenteritis illnesses, various types of skin infections including rashes, Tinea versiolor, boils and septic wounds and sores. Poor water is also related to conjunctivitis. Of all the communicable and non-communicable outpatients treated by the Princes Margaret Hospital in 2004, water-borne illnesses accounted for 70 per cent, or 5735 cases. Of these, sores or boils (Fig. 3) accounted for almost 71 per cent, whereas the more debilitating illnesses, diarrhoea and related problems accounted for about 10 per cent.

Not all water-borne diseases could be exclusively attributed to the poor waste management system. Activities that have similar effects include poor disposal of animal wastes and personal hygiene. According to Dr Stephen Homasi, Acting Director, Department of Health, the attribution factor also varies between the illnesses under consideration (Table 7). In the case of diarrhoea the direct causal relationship between human waste contamination and the incidence of illness varies from a low of 50% to a high of 80%. Using these marginal effects of human faecal contamination and the cost of treating each incidence, the total economic cost for Funafuti residents is estimated to be about AUD 15,500, with a range of AUD 13,000–20,000 (Table 8).

In addition, there are also worm infections. Empirical data for Tuvalu is available but Dr Homasi noted that worms are common among children under the age of five, and it is highly likely that they have had more than one type of worm infestation (Dr Stephen Homasi, Acting Director, Department of Health, pers. comm., November 2005). However, the hospital does not keep separate data on worm infestation. This is similar to what was found in Kiribati, where in a limited study of adults and children conducted for the World Health Organisation in 1998, it was noted that those surveyed were infected with two to three enteric pathogens or parasites. The pathogens identified were:

- dwarf tapeworm (Giardia lambia, *Hymenolepis* sp.)

- hookworm (Ancylostoma duodenale ova);
- whipworm (Trichuris trichuria ova)
- Entomoeba coli systs (Crennan and Berry 2002)

In addition, the government incurs costs associated with the running of the outpatient services and the pharmacy at the Princess Margaret Hospital. As discussed earlier, almost 70 per cent of outpatient cases are related to the water-borne diseases. Using the 2005 budget estimate for the Outpatients Service of the Hospital, the total economic health cost is about AUD 396,000 (Table 8).

Table 7: Economic costs of medicine associated with poor sanitation (AUD)

Human Health	High	Best	Low
Conjunctivitis	77	52	26
Diarrhoea*	8,915	6,687	5,572
Septic wounds/ sores	9,185	7,144	6,123
Boils	325	253	217
Fungal infection	324	252	216
Skin rash	970	755	647
Ringworm	102	76	64
Tinea	443	296	246
	20,343	15,514	13,111

* Includes the loss in earnings, assuming adults over the age of 15 may be absent from work 2 days in a week.

Table 8: Total health economic costs (AUD)

	High	Best	Low
Water-borne diseases	20,343	15,514	13,111
Worms	na	na	na
Pro rata outpatient service	396,494	348,805	249,146
Pro rata pharmacy	35,794	31,488	22,492
Total	452,630	395,807	284,749

Sources: Kilisimasi Setonga, Statistic Officer, Princess Margaret Hospital, Ministry of Health, Tuvalu; Irata Pulusi, Hospital Pharmacist; Tene Laupepa, Acting Pharmacist; Dr Stephen Homasi, Acting Director, Department of Health

Preventative measures: alternative water sources

Funafuti residents have substantially reduced their domestic use of groundwater, largely because of groundwater pollution. This suggests that they do know the water is polluted, but it is important to determine what is causing the contamination. Almost all homes (97 per cent of households) have rainwater tanks, which are now the main source of domestic water. Some households also use desalinated water supplied by the Department of Public Works, although desalinated water was installed to meet needs during drought periods. Public Works Department supplies approximately 27,000 litres of water per day, or 2.25 million litres in 2005. This was sold at AUD 16 per 45,000 litres to households and AUD 44 per 45,000 litres to corporations and ships. The total revenue earned was AUD 68,500. The retail price of desalinated water is only about 50 per cent of the true cost of producing desalinated water. There is also a sizeable quantity of bottled water consumed each year. Over the past three years, Tuvalu imported an average of 21,700 litres of water (unsweetened) at an estimated retail value of AUD 43,000.

Improvement in human waste management is unlikely to result in a total switch to groundwater use. It is possible, however, that the use of various water sources (e.g. tank, desalinated, bottled) would continue, although there may be some marginal change in respective quantities used. Using the Delphi method, the marginal shift in the consumption of water from different sources was assumed as summarised in Table 4. In the case of bottled water, it is estimated that 15–30 per cent of the purchase of bottled water could be attributed to poor water quality (a large portion of the consumption of bottled water is believed to be due to lifestyle issues and convenience). Similarly, it is assumed that, even with the improvement in the quality of groundwater, households will continue using rainwater tanks. Rather than having one and a half rainwater tanks of 13.1 cubic metre capacity, however, a single tank will suffice. The total economic cost of preventative water-related measures is estimated to be approximately AUD 74,000 per year (Table 9).

Table 9: Economic costs of alternative water sources (AUD)

	High	Best	Low
Desalinated water	49,961	37,470	12,490
Rain water	44,584	27,020	-
Bottled water	14,676	9,784	4,892
Subtotal of water costs	109,220	74,275	17,382

Coastal fisheries and coastal ecology

International experiences show that increased pollution from leaking septic tanks affects the productivity of the coastal waters (Kaly 1998). In addition to containing bacterial and other pathogens, human wastes are high in organic matter and inorganic nutrients such as nitrites, nitrates and phosphates. Such discharges in areas of limited water circulation and dilution are known to cause eutrophication of lagoons, which results in the growth of blue-green algae, changes in species composition, and decrease in biodiversity (Fig. 2).

Information on the effect of human waste on coastal environments in Tuvalu is limited. The recent audit of a limited number of sites in the Funafuti lagoon (carried out as part of the Waste Management Project) suggests that changes have occurred since 1996 in the local ecosystem and in the abundance of reef-associated organisms in the Funafuti lagoon. Areas with high effluent discharges tend to have a decrease in hard coral cover and some coral-associated fishes, and an increase in turfing and blue-green algae (Kaly 2001a). Quantitative information on such impacts is not available, however; there is also no data available on the impact of such changes to subsistence and commercial fisheries output.

Recent studies reported that subsistence fishing in 1998 contributed about 5.5 per cent of the gross domestic product, as compared with the market fish production contribution of 0.2 per cent of the gross domestic product (ADB 2002). In Funafuti, almost 50 per cent (334) of households regularly fish for subsistence and/or sale, in either inshore or offshore waters (Census Report 2002, tables H26 and H27; see Government of Tuvalu 2002). The actual volume of fish harvested from the Funafuti lagoon is unknown. During the period 1997–2001, an annual average of 47 tonnes of fish was sold through the National Fisheries Company of Tuvalu. At the current (2005–2006) price of AUD 3 per kilogram, the value of that quantity of Funafuti-caught fish would be AUD 142,000.

Evidence from elsewhere in the Pacific (such as Tonga) suggests that increased pollutants negatively affect coral growth, stimulate algal growth, and affect coastal fisheries (Kaly 1998, Kaly 2001a, Kaly 2001b). In the Fanga’uta Lagoon, Tonga, for example, total fisheries harvests declined by approximately 40–50 per cent in 10 years. Based on this information, a best estimate of a 4 per cent decline in Fanga’uta fisheries due to waste-related pollution (and a high estimate of 10 per cent), was assumed (Lal and Takau 2006). If a similar impact is assumed for Funafuti, the fisheries economic cost is estimated to be AUD 5,700, with a range of AUD 3,000–14, 000 per year.

Total economic cost associated with current sanitation status

The total economic costs associated with the residual effects of the current septic tank-based waste management system is about half a million dollars, and with a range of between AUD 304,000 and AUD 576,000 per year. Of this, the human health costs are the highest, at about 83 per cent. These costs are borne by the government. Other costs, largely borne by private individuals, are small in comparison (Table 10).

It is noted that the cost estimates derived in this study are based on a partial analysis only. They do not, for example, reflect considerations of the value of human suffering, changes in the ecosystem dynamics, or changes in species composition caused by increased pollution. If such costs were included, the economic costs may be much higher.

Table 10: Total economic cost associated with current status of human waste management (AUD)

	High	Best	Low
Human health	452,630	395,807	284,749
Desalination water	49,961	37,470	12,490
Rain water	44,584	27,020	-
Bottled water	14,676	9,784	4,892
Fisheries	14,190	5,676	2,838
Total economic costs	576,040	475,758	304,969

5 Economics of alternative sanitation systems

The Government of Tuvalu has considered several sanitation systems in the past 15 years, including a centralised reticulated system, mini-treatment plants, repairing the existing septic tanks, replacing existing septic tanks with plastic ones, a hybrid system that uses reduced quantities of water, and the use of composting toilets (see, for example, ADB 1996; Falkland 1999; Falkland 2002).

Of these, only the household-based systems are considered viable options for Funafuti. The pour flush system is highly undesirable on environmental grounds, however, because there is no treatment of waste, and groundwater contamination is high. The large-scale reticulated system was recommended by ADB (1996); while it is the preferred solution from an environmental viewpoint, the recurrent costs of the sea water reticulated sewerage system are not affordable for the government or the residents (as noted by AusAID 1998). The large-scale reticulated system would be based on establishing a network of pipes for a sea water-based second class water system, a sewage disposal system connecting less than 1000 households in Funafuti, together with a centralised treatment plant. The total estimated cost would be AUD11.7 million, with recurring costs of about AUD 30,000 per month (AusAID 1998).

Management options

Given the high costs of the large-scale reticulated system, the government must choose from one of several household-based management options.

1. Do nothing—business as usual

The "do nothing" option is business as usual, with construction of poorly designed flush systems continuing. Despite having draft building codes and Kaupule bylaws, neither the Public Works Department nor the Kaupule has strictly monitored the construction of septic tank systems. Under this option, leaking of septic effluent into surrounding waters will continue, and associated pollution of groundwater and coastal lagoon waters will increase. The problem is likely to worsen as the population grows, and if the predicted climate change effects become a reality, increasing the incidence of extreme weather events, regular floods and droughts will become a regular feature of life in Tuvalu. Under this option, the expected human health costs and the need for desalinated and other sources of drinking water will increase. In the long term this is not an option if Tuvalu is to achieve its national development goals.

2. Repair existing septic tanks

2a. Replace existing tanks with plastic tanks

2b. Replace existing tanks with concrete tanks

There are two options for repairing septic systems. One is to dig the current septic tanks out and replace them with concrete tanks, changing all piping connections. Alternatively, existing tanks can be replaced using plastic septic tanks. In both cases, the current system is repaired or replaced so that proper design of the septic tanks and soak pits is ensured. These options would require a once-off capital investment plus a regular maintenance cost for the clearing of septage (Table 11). Each household would continue to use an average of about 51,000 litres (l) of water annually.

3. Hybrid toilet system with mini treatment plant

A hybrid system is based on the flush toilet and tank system, in which the volume of water needed is drastically reduced. Solids are separated and the liquid goes into a smaller septic tank; organic matter is broken down through bacterial action. The hybrid system operates in a manner similar to aeroplane toilets, in which a partial vacuum suction is used to clean the pans. The volume of water is reduced to 770 l per year. Such a system would still need to be linked to a sewage treatment system.

4. Mini treatment system

The mini treatment system involves linking three to four households together to a mini-treatment plant which separates solids from liquids. The treated solid waste is used for composting, while the nutrient-rich liquid effluent is sprinkled on grass. This is a highly capital-intensive option (Figure 4).

5. Composting or waterless sanitation system

Composting toilets constitute an above-ground, dry (waterless) sanitation system. Many different designs and off-the-shelf composting toilets are available, and they vary in cost depending on the material used and the local cost of labour (Del Porto and Steinfield 2000). In Tuvalu, several designs were trialed under the AusAID Waste Management Project, and more recently under the IWP (Figure 4).

Composting toilets are usually built with the pan sitting on a high platform and the collection container or tank fitting under the platform. The waste collection container or tank can be either removable or fixed, depending on the technology; easy access to the container or tank is needed for removal of the dried compost. The system relies on the use of carbonaceous material, such as dry leaves, untreated softwood shavings or coconut fibres to balance nitrogen in human excreta and provide aeration. Any type of organic material can be used for personal cleaning and dropped in the toilet. The decomposition process produces a soil-like humus or compost, which can be used as a fertiliser after sufficient time has been allowed for the destruction of disease-causing organisms and pathogens (usually about a year). The compost material is emptied from the end of the chamber every 6 to 24 months, depending on the size of the chamber and the frequency of use.

5a. Add-on system

An add-on system involves setting up the compost system adjacent to the existing house, like a traditional outhouse. The cost of the add-on system includes the cost of the composting toilet plus the cost of constructing the hut. Care has to be taken in the toilet and piping connections, as otherwise the system may not work properly, causing a bad smell in the pan area and poor compost production.

5b. Built-in system

Composting toilets can be easily incorporated in the design of a new house. Any composting toilet design can be applied, but the entire component must be included in the building design. The tanks or containers should be easy to access so that it is easy to remove compost from the tanks or containers. New compost toilets are more cost effective because the need to construct an outhouse is avoided (Table 11).

Comparison of economic costs

Comparing the cost of alternative options can help a decision-maker choose between options. From an economic perspective, the option that generates maximum net benefits is the preferred choice. Where the benefits are comparable, as is assumed in this case — all options generate (at a minimum) total benefits equivalent to the current costs to human health, the costs of preventative measures taken in relation to alternative water uses, and the value of the loss in coastal fisheries — the comparison than becomes one of economic costs of the various options.

The do nothing option, which is the current status, costs the country approximately AUD500,000 per year, or an annual household cost of AUD 700. The annual household cost estimate is comparable to the annualised cost of a composting toilet built when a new home is constructed. Its initial cost of establishment, including the cost of purchasing the raw material and construction at the time of new house construction, is AUD 4000. Assuming a discount rate of 10 per cent and that the composting toilets last at least 10 years, the annualised economic cost of new composting toilet is AUD 700 per household. On the other hand, if the composting system was added to an existing home, the annualised household cost would be about AUD 900. In addition, there is an economic benefit valued of about AUD 80 per household from the compost/soil that is generated. Moreover, since composting toilets do not need water, Funafuti residents can expect to realise an economic savings of about AUD 3,000 in the shadow value of water that would have otherwise been used in toilet flushing (Table 11).

There is little difference between the annualised cost of the add-on composting toilet system and option 2 (repair the septic tanks); the new compost system is the slightly cheaper option, if one ignores the value of water savings and new soil creation. The choice of technology based purely on financial costs suggests the following order of preference: (1) Composting toilets—new construction (no outhouse needed; option 5b); (2) Replace leaking septic tanks with plastic tanks (option 2a); (3) Composting toilets—add on (option 5a); (4) Replace septic tanks with concrete tanks (option 2b).

If, on the other hand, the scarcity value of water used in flushing in a septic-based system is also considered, the composting toilet system is economically the most desirable. This system, either as an add-on to existing households or built at the time new house construction, would produce positive net returns, even considering the initial capital costs, whereas the septic tank-based systems become economically unviable. Replacing leaking septic tanks, using a hybrid system, and mini-treatment plants are economically unviable.

On the other hand, other systems, such as the hybrid system in which water consumption is reduced almost one hundred fold, address the water use issue. The hybrid system installation would still need to have a parallel "replace leaking septic tank" option, or a mini-reticulated system. The hybrid system combined with repair of leaking septic tanks would cost approximately AUD 1600 per year. In comparison, the hybrid system plus the mini-reticulated system is the most expensive, costing about AUD 18 000 per year.

If all Funafuti residents were to convert to composting toilets, Tuvalu could expect to save approximately AUD 2 million each year, compared with incurring a cost of approximately AUD 100 000 annually, including the benefits derived from improvements in sanitation.

In conclusion, taking into account economic and environmental considerations,and economic net benefits are positive the order of preference of technology is (Table 12):

1. Composting toilets—new

2. Composting toilets—add on

The following systems are unviable:

- replace leaking septic tanks with plastic tanks
- replace septic tanks with concrete tanks
- hybrid (plus septic)
- mini-treatment system (unviable).

Feasibility considerations and choice of technology

The adoption and sustainability of a technology is determined not only by economic and environmental factors, but also by other feasibility factors, such as the nature of the physical environment where the tank is installed, availability of water and social acceptability.

Physical environment

Current problems associated with leaking septic tanks can be addressed by fixing the leaking septic tanks. This can be done, as stated above, by replacing the current poorly designed septic tanks with properly designed and water-tight concrete- or plastic-lined tanks.

Experience in the use of the plastic tanks in government houses show that plastic tanks, although cheaper than their concrete counterparts, are not suitable in areas subject to flooding and high water table levels.[3] Even in areas where the groundwater table is found at a depth of around 1–1.5 m, during heavy rains and king tides the groundwater level rises, causing plastic septic tanks to float. To keep the tanks in place, holes were be drilled in the tanks, resulting once again in effluent seepage from the septic tanks, thus defeating the purpose of replacing the poorly functioning septic tanks.[4]

This option only addresses part of the problem. It does not solve the pollution problem, particularly during dry season — which lasts at least three to four months per year — and times of drought, when residents resort to using beaches once again.

[3] In some parts of Funafuti, the water table is found only .3 m below the surface (Falkland 1999).

[4] It is possible to incorporate a ring of concrete to weight the tanks; although this would avoid leakage, it would add to the costs.

Social acceptability

As seen above, composting toilets are most economical and environmentally friendly technology. Their social acceptability is, however, uncertain. Trials with composting toilets in Tuvalu and elsewhere in the Pacific, such as Kiribati, have demonstrated that such systems are technologically feasible, but community members are reluctant to embrace the technology for social reasons. The main obstacles include unfamiliarity with the technology, and personal attitudes and preferences.

Figure 4A: Alternative human waste management system (individual composting toilet system)

In Kiribati, for example, a community health officer noted that "it took us 20 years to get used to the flush toilet, at first we didn't like it for a lot of reasons" (SOPAC 2002). Flush toilets then took on a prestige value and were found to offer convenience, comfort and privacy (once the toilets became incorporated in the house). Flush toilets thus became the norm. The use of composting toilets was seen as going backwards, particularly because the early designs utilised the add-on (outhouse) approach. Although later composting toilet designs incorporated the toilets as an integral part of a home, their acceptability is likely to be slow, even if they offer health benefits and water savings. As noted by Van Wijk (cited by Crennan and Berry 2002: 15), family health is rarely given as a reason to install a toilet. Even in the case of the conventional flush toilet system, the World Bank noted that these were installed to provide a higher level of convenience, not better health (cited in Crennan and Berry 2002: 15).

Figure 4B: Centralised reticulated human waste management system

People also have some concerns about the health aspects of using the composted material. Since human waste is a major source of waterborne disease, questions have been raised about the survival rate of key pathogens. International studies show that there is little risk of disease infection from handling composted material after 6 months of composting.

Studies from Kirimati Island in Kiribati show that within six months of composting, eggs of pathogens such as whipworm (Trichuris trichiura) shows signs of degradation. Similarly, within six months there are no more signs of cysts of Giardia lamblia, although these were present in large numbers in fresh waste. There is also a total absence of feacal coliform, feaecal streptococci, shigella and salmonella bacteria in the composted samples. The pH measures (7.2–7.5) are also within the range expected of mature compost (SOPAC 2002).

Based on these studies, it appears that the risk of disease from using properly composted waste is most likely significantly lower than the health risks posed by the current poor sanitation system in Funafuti.

6 Conclusion and policy recommendations

Tuvalu faces significant challenges in relation to the management of its human wastes, *fekau o tino*. Taking a conservative approach, this study estimates that the current largely septic-based system of liquid waste management is costing the nation about AUD 500,000 per year. This estimate is based on partial analysis of the costs of poor sanitation on human health, the preventative costs incurred by individuals and government in the use of alternative sources of water (including rainwater tanks, bottled water and desalinated water), as well as limited costs associated with impacts on coastal fisheries.

A number of alternative options are available, including fixing the current septic system, establishing a centralised reticulated system, and household-based sanitation systems based on composting toilets. However, the feasible options available to the government for improving the sanitation system are constrained by both the availability of financial resources and Tuvalu's unique atoll environment, in which the groundwater is within 2 m of the surface in some areas. The choice of an alternative system is further constrained by the fact that Tuvalu experiences dry weather for up to three to four months of the year, and extended periods of drought. In addition, in periods of rainy seasons and king tides, much of the land area is subject to regular flooding.

A sanitation system based on composting toilets is (i) the cheapest economically and (ii) does not rely on the availability of water; thus composting toilets address both the financial and environmental limitations present in Tuvalu. The annual cost to Funafuti of establishing and maintaining a composting toilet system as part of a new home is less than the estimated current total cost of existing human waste management practices (in terms of economic costs associated with human health, preventative costs and losses in coastal fisheries productivity). The initial capital investment necessary to convert existing homes to composting toilets is approximately the same as it would take to replace the leaking septic tanks. But even with an efficient operating septic tank system (which would eliminate the human health, preventative and fisheries-related costs), the continued use of water flush toilets would result in a net negative economic benefit, largely due to the high shadow value of scarce water; desalinated water is costly throughout the world because of high energy and operating costs.

A composting toilet system established using local materials in Tuvalu has a net positive economic benefit. Despite their economic benefits, however, acceptance of composting toilets is likely to be slow due to social resistance on the part of community members.

To encourage the adoption of composting toilets, a multi-pronged and sequenced program is needed that incorporates the following:

1. A massive education program highlighting the merits of using composting toilets vs. other management options, including the no action option. Economic values estimated in this study could help provide more focussed and objective quantitative information that can demonstrate the economic costs of the current system as compared with the expected net benefits of changing over to the alternative system, including the savings in freshwater.
2. Development of an integrated liquid waste management plan, involving key stakeholders including the Department of Public Work, Local Kaupule, Department of Environment and the Ministry of Health. The liquid waste management strategy must be linked to the national budgetary process through the national sustainable development strategy, or the Kakega II.
    a. *Institutional reforms*: In the outcome-focussed plan, it is imperative to establish an interdisciplinary waste management task force, and clearly define the roles and responsibilities of each government organisation involved in waste management, while emphasising the shared responsibility for the management of liquid wastes in Tuvalu. Each agency

must be adequately resourced and their program of work coordinated and harmonised.

b. *Economic instruments*: Adopt economic incentives, such as subsidies, to bring about behaviour change.

c. *Legislative instrument*: Develop appropriate liquid waste management legislation in which composting toilet system are made mandatory in the design and construction of all new homes, and new additions to existing homes. The cost of doing so could be subsidised by the government. An effective monitoring and enforcement system would also be needed.

3. The government could approach a development partner to assist with conversion of the existing septic system with composting toilets for households that show commitment to the use of an ecological sanitation system. The government could also consider approaching development partners for assistance under the Clean Development Mechanism of the Kyoto Protocol.

In conclusion, Funafuti has very few choices available to it with respect to its management of human wastes. If the country does not urgently tackle this issue, the problem is likely to become more acute as population increases, and the predicted climate change-related impacts become a reality.

Table 11: Economic costs of alternative household-based human waste management systems (AUD)

	New septic-based toilet	Fix existing septic system	Plastic septic	Composting (add-on)	Composting (new)	Hybrid	Hybrid + fix septic	Mini treatment
Fixed cost per unit	4,200	4,000	3,600	5,200	4,000	4,200	8,200	150,000
Operating cost per unit per year	240	240	240	25	25	50	290	400
Annualised costs per household	924	891	826	871	676	734	1625	18,019
Water saving per household				2,839	2,839			
Annual compost value per household				21	21			

Table 12: Funafuti's aggregate economic net benefit associated with each liquid waste management option (AUD)

Sanitation options	Initial capital establishment investment	Annualised cost	Water savings	Compost soil benefits	Annualised option's net benefit (loss)	Health, preventative and environmental benefits (costs)	Total net economic benefit (loss)
Do nothing option						(475,758)	(475,758)
New septic tank	2,683,800	590,136			(590,136)	475,758	(114,378)
Fix septic tank	2,556,000	569,337			(569,337)	475,758	(93,579)
Plastic septic tanks	2,300,400	527,740			(527,740)	475,758	(51,982)
Compost (add-on)	3,322,800	556,745	1,814,363	52,467	1,310,084	475,758	1,785,842
Compost (new)	2,556,000	431,952	1,814,363	52,467	1,434,878	475,758	1,910,635
Hybrid + septic	5,239,800	1,038,063	27,215		(1,010,848)	475,758	(535,090)
Mini-treatment	23,962,500	11,514,105			(11,514,105)	475,758	(11,038,347)

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Annex 1: Data collection methodology

This study is based on primary and secondary data collected from several different sources using a mixed methodology. Relevant data and expert opinions were collected through reviews of published and unpublished secondary literature on waste in Tuvalu and waste management in the Pacific, and interviews with experts (i.e. the Delphi method). In addition to a general demographic and economic profile of the country, sector-specific national level qualitative and quantitative information was collected from different government stakeholders, including the Department of Health, Public Works Department, Ministry of Fisheries, and Department of Environment, and the Local Falekaupule. Government departments' annual reports, consultancy reports, and published and unpublished government statistics were the main source of published and unpublished information.

Secondary literature was used to undertake a situation analysis of stakeholders and organisations and the formal and informal rules within which they operate. In addition, wherever possible, qualitative and quantitative data/ statistics were also collected. These related to:

1. The current status of impacts related to wastes and the proportion of these attributable to human waste pollution (High, Best, and Low estimates). Categories included:
    a. Health impacts — types of diseases, number of people suffering, number of days of illness, average cost of medicine per incidence, average costs of transport, doctors fees etc. per incidence;
    b. Fisheries loss — types of fishes affected, changes in volume caught attributable to wastes, value of lost fisheries catch;
    c. Changes in ecosystem and environmental services; and
    d. Tourism — number of tourist arrivals, their annual expenditures, and an estimate of the change in the number (if known) due to recent images of poor health.
2. Known waste management options, including information about
    a. Type of technology;
    b. Capital costs and life of technology;
    c. Operating Costs, if any;
    d. Regular operational/ maintenance efforts required; and
    e. Feasibility of meeting the operational / maintenance efforts required.

Where experts and other informants were consulted, a structured, semi-structured, and open-ended interview format was used to elicit information. Where there was a large variation in different data sets or information collected from different informants, triangulation of different data sources was attempted. In some cases, when differences where found, these were cross checked and verified using published secondary information and/or by other stakeholders familiar with wastes in Tuvalu.

Using the results of these interviews and data collected from other sources, typical impact models associated with wastewater effects were constructed for a typical household. These models were then be used to assess the financial costs of different categories of impacts of wastewater on human health, fisheries, coastal ecosystem.