WASTE MANAGEMENT DEVELOPMENT IN THE MALDIVES

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Introduction

The Republic of Maldives is situated south of India, between 7^{o} north and 0.5^{o} south. It comprises some 1,200 atoll islands of which 200 are inhabited by approximately 300,000 people. The Maldives is an Islamic state. These days the Maldives is popularly known as a nation of emerald, tropical islands that beckon those in search of an idyllic holiday. Its history is long, dating back two millennia or more.

In 2000, the Government initiated the first regional development project, funded by the Asian Development Bank and the Islamic Development Bank. The object was to make institutional, infrastructure and environmental improvements in two regions distant from the centrally located capital, Male. These are the northern region is centred on the island of Kulhudhuffushi and the southern region in Addu Atoll on the islands of Hithadhoo, Feydhoo and Maradhoo, which are connected by causeways.

The infrastructural development comprised solid waste management facilities, a pilot sewerage scheme and a new road that included causeways and bridges designed to improve water flow into the atoll. This paper focuses on the solid waste management and pilot sewerage scheme aspects of the project.

Project Overview

The project was managed within the Maldives by the Ministry of Planning and National Development (MPND). They reported to a Project Steering committee whose members came from a number of Government ministries. The MPND created a Project Management unit (PMU) to manage the day to day aspects of the project.

A consultant team comprising personnel from New Zealand, UK, Australia and the Maldives was appointed by the PMU to provide design and contract management expertise.

The first regional development contract included the major elements of:

- a new road (approx 13km long) linking the 4 major islands in Addu Atoll
- causeway and bridge improvements along the length of the new road
- a pilot sanitation scheme in Kulhudhuffushi in the north of the country
- provision of two solid waste processing sites together with plant and equipment
- establishment of two Regional Development Management Offices (RDMOs) designed to promote regional development in both northern and southern regions
- a programme of groundwater investigations undertaken in 13 focus islands to establish baseline conditions and make provision for on going monitoring.

For the solid waste and sanitation components, the emphasis was to design these schemes in such a manner that they could be replicated on other islands.

The Maldives has some unique characteristics. The islands are generally small, typically only about 1 or 2km in length and often less than a kilometre wide. They are low lying with few areas more than 1m above the high water mark. They have a coral fringing reef that provides protection from ocean swells. Most islands are heavily dependant on a thin lens of groundwater that supplements rainwater for drinking and hygiene, particularly during dry periods that can last 3 to 4 months. The excessive use of the groundwater lenses, which results in saline intrusion, has occurred in many islands. Also of concern is the potential contamination of this vital resource by solid waste leachate and human waste.

Given the small populations on most islands and the Government's limited resources, the provision of infrastructure such as roads, water and sewerage systems is difficult to provide economically. Also, householders have a limited capacity to pay for extra charges (e.g. property rates, user charges etc). Thus, one of the project objectives was to propose low cost and low technology solutions that could if successful be replicated elsewhere.

Solid Waste Management

Background

The project included firstly developing a waste strategy for the Southern Development Region and the Northern Development Region and then developing solid waste plans that detailed waste management solutions for the islands of Hithadhoo, Feydhoo and Maradhoo in the south and the island of Kulhudhuffushi in the north. The method adopted for developing a solid waste plans is illustrated by Figure 1.

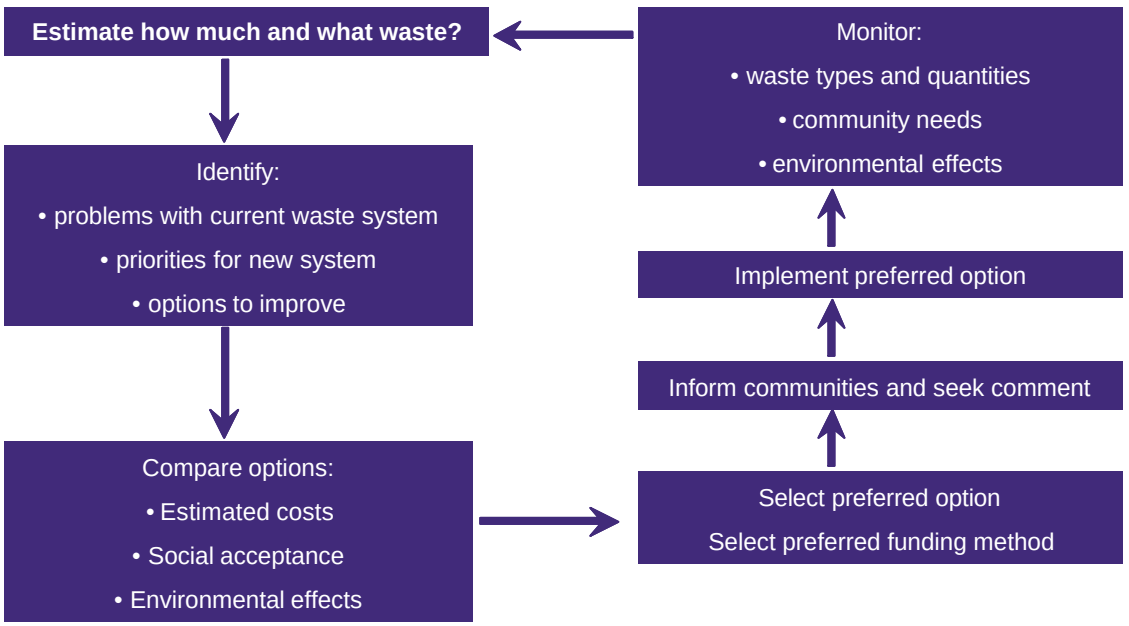


Figure 1: Solid Waste Plan – Method of Development

Existing Solid Waste Management

Generally solid waste was disposed of indiscriminately by uncontrolled tipping in unoccupied land or on beaches, or used to reclaim land by filling lagoons.

In the south, there was concern within the communities about current waste disposal practice. Three contractors had offered household waste collection services on Hithadhoo. Two had discontinued the services because too few householders subscribed.

Proposed Strategy

The initial objectives of the strategy were:

- to confine waste processing and disposal to a single location on one of the islands the Southern Development Region (SDR) and to identify and develop a waste processing and disposal facility on each of the focus islands in the Northern Development Region (NDR)
- to facilitate the transfer of waste to the central location
- to have regard to environmental and economic costs and benefits in developing and operating a solid waste management system
- to monitor solid waste types and quantities
- to monitor users of the system so as to learn about the perceived benefits and desired levels of service
- to ensure the management of waste does cause a nuisance or adverse health effects
- to introduce user charges gradually
- to carry out a public information and education campaign and to maintain an up to date information service
- to integrate where practicable or necessary with a national solid waste management system
- to minimise solid waste when affordable or cost effective.

Investigations

Investigations involved researching waste generation information gathered for similar island communities, consultation with Government agencies and local communities, inter-island transfer of waste, and site inspections to identify possible locations for waste management sites.

General issues recorded in the reports of other studies and reported during consultation as part of the project included:

- environment effects of current waste management activities including:
  - nuisance from flies, smoke and bad smells
  - unsightliness of scattered waste

  - large area of land affected by waste disposal
  - leachate from waste damaging the groundwater resource and ecosystems
- economic effects of changing the current waste management activities including
  - utilisation of land that may otherwise be used for residences or other activities
  - cost of providing collection and disposal services
  - cost of recyclables collection programmes
  - integration of port and waste management activities for the export of recyclables
- social needs to effect change including
  - need for informing and educating residents and others
  - getting people to separate waste to enable improved waste management
  - institutionalising waste management because residents now are less inclined to provide voluntary services for waste management activities such as reducing, burying, burning waste etc than they used to be
  - finding waste management sites away from people who may be adversely affected.
- health and safety risks associated with:
  - waste items that could cause injury to people, particularly children playing amongst the waste
  - emissions from burning refuse (MfE, 1997)
  - contamination of groundwater that is used for water supply.

Sea transport services convey people and goods to and from the islands. It has been reported (McFayden, 2000) that sea transport from Male to the focus islands has over 80% utilisation of available capacity and sea transport from the focus islands to Male has approximately 14% passenger and 31% cargo utilisation. This indicated there may be capacity for the transfer of selected recyclable material or hazardous waste to Male for processing, disposal or export.

In the north, the development and operation of facilities for the transfer of solid waste from one or more focus islands to a waste processing and disposal facility located on another island was considered an inappropriate strategy. Such a strategy would carry high risks and potentially high costs because of the lack of knowledge about waste and the absence of experience in waste handling, processing and disposal using a systemic approach.

Most land area on the islands of Maradhoo, Maradhoo-Feydhoo, and Feydhoo was occupied with dwellings or businesses. On Hithadhoo there were areas of unoccupied land.

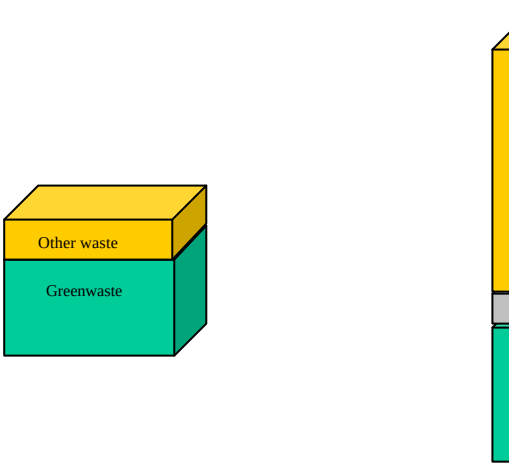
In the north, the larger islands of Kulhudhuffushi, Dhidhdhoo, and Hanimaadhoo have considerable land use demands, particularly Dhidhdhoo. The smaller islands of Kelaa, Filladhoo, Baarah, Nolhivaramfaru, Nolhivaram and Kumundhoo all have extensive areas of natural vegetation and low land use pressures.

Waste Management System Design

Waste quantities were estimated on the basis of present and forecast future populations provided by others and waste generation factors determined for South Pacific Islands (Woodward, 2000).

Waste was considered in the broad categories of greenwaste, construction and demolition (C & D) waste and other waste. Figure 2 illustrates these three broad categories in terms of estimated quantities at present and in Year 2020 for the SDR.

Figure 2: Estimated Waste Quantities



Now

Per person	**<1 kg / day**
Other Waste	**1,700 tonnes/year**
Greenwaste	**3,600 tonnes/year**
Total	**5,300 tonnes/year**

Year 2020

Per person	**1.9 kg/ day**
Other waste	**8,600 tonnes/year**
C & D Waste	**3,400 tonnes/year**
Greenwaste	**5,100 tonnes/year**
Total	**17,100 tonnes/year**

Estimated quantities of solid waste generated on Kulhudhuffushi in the north (NDR) are given in Table 2.

Table 2: Estimated Quantities of Waste in the Kulhudhuffushi

Waste Type	Year 2000 t/yr.	Year 2015 t/yr.
Municipal waste	900	2,600
D& C waste	0	600
Greenwaste	1,200	2,000
Totals	2,100	5,200

Basis of estimates: Woodward (2000)

Land area requirements for each waste management site were determined on the basis of the estimated waste quantities for the design period. Each site required areas for reception, processing, storage of waste and for the disposal of residual waste.

Site investigations were carried out on Hithadhoo in the south and Kulhudhuffushi and possible sites were characterised in terms of potential environmental, social and economic effects. Final selection of the two waste management sites (one on Kulhudhuffushi and one on Hithadhoo) was made in consultation with Government agencies and local communities. The selected sites were a far as possible from residential areas and near power generating plants.

Ideally the waste disposal areas would have been lined with leachate collection and treatment facilities. However, cost estimates indicated that such a landfill design was well beyond the available budget. The designs focussed on minimising the adverse effects of leachate through waste input control and less costly mitigation measures inherent in good site selection, appropriate design detailing, and good residual waste deposition methods.

A similar design was adopted for each site and comprised:

- incoming waste reception building
- a waste deposition area
- greenwaste tipping, shredding and storage areas (greenwaste is to be used as waste cover material)
- recyclables storage and baling area (recyclables are to be transferred to Male)
- hazardous waste storage area (hazardous waste is to be transferred to Male)
- circumferential litter catch and access control fence.

As part of the project, waste management equipment was procured for each waste disposal site (Table 3).

Table 3: Waste Management Equipment

Description	Comment
Bull dozer	Machine to spread and compact waste
Greenwaste shredder	Machine to pulverise greenwaste for use as cover
Front end loader	Machine to shift cover material and baled recyclables
Recyclables baler	Machine to compact recyclables into bales for efficient transport

Construction and Commissioning

Construction was carried by local contractors and equipment was procured on the international market. Waste management operations plans were prepared and operations contracts were let after tendering the work on the local market. Training in plant operation and maintenance, landfill operation techniques and health and safety procedures was provided to the successful tenderers prior to the sites being opened for public use.

Pilot Sewerage Scheme

Overview

The island of Kulhudhuffushi was selected for a pilot sewerage scheme. This island of approximately 172 hectares supports a population of approximately 7,300 people.

The objective of the pilot scheme was to identify a set of sewage collection, treatment and disposal solutions that, after a period of monitoring and refinement, could form a solution for the island and other islands. Key issues that were to be taken into account were appropriate technology, affordability and water conservation.

Site investigations and design work were carried out in Years 2000 and 2001. Construction and commissioning were undertaken in Years 2002 and 2003.

Site Investigations

Site investigations included groundwater characterisation, gathering knowledge about existing systems and associated issues, and consultation with Government agencies and the local community.

Traditionally, inhabitants of atoll islands have depended on the freshwater lenses for fresh water supply. Such lenses form in the coral and coral sands, floating on saline water, and are recharged with rainfall. Population growth and uncontrolled discharge of wastewater and solid waste have resulted in increased levels of groundwater contamination.

Groundwater investigations involved:

- drilling of salinity monitoring boreholes
- inspections, salinity tests, water level measurements of groundwater at wells and other locations
- measurement of water levels and salinity with data loggers at selected sites
- water quality sampling, testing and analyses for water chemistry and microbiology
- electromagnetic (EM) surveys at selected cross sections and spot locations
- estimation of the extent of freshwater lenses based on the above procedures and tests
- estimation of recharge and sustainable yield
- estimation of current extraction rates and consumptive use
- estimation of available capacity of freshwater lenses.

Results of freshwater lens characterisation for the study islands in the Northern Development Region (NDR) are reported in Table 4.

Table 4: Summary data for freshwater lenses in 11 NDR islands

Island	Population (Dec 2000)	Average freshwater zone thickness (metres)	Freshwater lens area (hectares)	Approximate freshwater zone volume (million litres)	Estimated Sustainable Yield (litres per person per day)
Hoarafushi	2,767	0.5	31	45	50
Ihavandhoo	2,306	3	30	270	60
Dhidhdhoo	3,349	2	34	200	60
Kelaa	1,892	8	107	2,570	255
Filladhoo	883	0.5	11	15	40
Baarah	1,570	6	83	1,490	240
Hanimaadhoo	1,240	4	171	2,050	620
Nolhivaramfaru	615	0.5	33	50	200
Nolhivaram	1,873	4	114	1,370	275
Kulhudhuffushi	7,242	7	105	2,200	65
Kumundhoo	1,245	8	120	2,880	440

Source: Falkland, A C (2001)

For Kulhudhuffushi, the results indicated a low sustainable groundwater and contaminated groundwater beneath urban areas. Contamination was caused by faecal coliforms and, in some instances, by phosphorus and nitrogen.

Investigating existing methods of sewage management revealed that human excrement is discharged to septic tanks, most commonly using pour-flush toilets, and sullage is discharged directly to ground using flood irrigation. Septic tank effluent is discharged to soak pits and, because the groundwater is at a shallow depth, the discharge is commonly directly to groundwater.

Typically, a septic tank system comprises a cylindrical, concrete, primary chamber (approximately 1 m^3), a cylindrical, concrete secondary chamber (termed a "filtration tank", approximately 0.2 m^3) and a soak pit. Inspections showed that inlets and outlet tees were often absent, and that tanks were often full of sludge. A thick scum mat common in septic tanks was not observed in any tank. There were no mechanised septic tank pump-out facilities on the island.

Scheme Concept

A sewerage scheme comprises the components of sewage collection, treatment and disposal (or re-entry into the natural environment).

Given that site inspections revealed a considerable investment in septic tanks that were, in most instances, in sound condition, a septic tank effluent collection system was adopted for sewerage. Benefits of such sewerage included:

- being able to lay sewers at low grades, which resulted in sewers at shallow depths above the groundwater level and avoiding pump-lift stations.
- the use of small diameter sewers because only settled sewage needed conveyance and septic tanks tend to buffer peak flows
- the reduction of the scheme capital cost.

Given that groundwater is an important resource and the estimated sustainable yield per capita was low, the return of treated sewage to the groundwater was adopted as an appropriate objective. However, such a solution would require treatment that would minimise the risk of adverse health effects.

Resources on the island in terms of construction materials and personnel trained in mechanical and electrical systems were limited. However, a further objective was to utilise as much local materials as possible to minimise importation needs and personnel to develop local knowledge and to provide training in construction, operation and maintenance.

Objectives of the pilot scheme were:

- to demonstrate that land disposal of effluent is possible for the island environment (thereby ensuring groundwater is recharged)
- to achieve a compact sewage treatment plant using appropriate technology
- to achieve an effluent quality suitable for discharge to groundwater
- to provide a modular system that would be extended to serve the entire urban area and be located in vacant or unwanted land on the periphery of islands.
- to provide flexibility so as to accommodate increased water usage in the future and enable a centralised sewerage system should this be required in future.

Scheme Design

A residential area on the south of the island was selected for the pilot sewerage scheme. It comprised 59 premises, which were predominantly residential dwellings but included the regional development office, the atoll office, a guest house and an information centre. The estimated population was approximately 300 persons.

An average sewage flow factor of 50 litres per person per day was used. This was based on people using 10 litres of flush water and 40 litres of bathing water per person per day. This was considered conservative as:

- most sullage is disposed onto ground, not through the existing septic tank systems
- there is no reticulated water supply
- most toilet systems are pour flush not cistern flush.

A design average daily flow rate of 15 m^3 and a design peaking factor of 2 were adopted.

The sewerage system was designed using the USEPA manual "Alternative Sewer System Design". A sewer pipe size of 100 mm diameter and a sewer grade of 1: 350 were adopted for design. Sewer cleaning eyes were included at relevant points (such as at

changes in pipe gradients and at bends). Manholes were provided at intersections in the sewerage system so that maintenance can be undertaken.

A recirculating granular medium filter process was selected for the treatment of septic tank effluent. Benefits of such a treatment system were considered to include:

- appropriate technology in terms of construction requirements and treatment process
- high effluent quality
- flexibility in terms of facilitating modular construction.

The sewage plant design comprised:

- an inlet manholes fitted with fine screens for intercepting any solids in the septic tank effluent
- a combined pump station and re-circulation tank
- three granular medium filters, with to enable operation with one filter out of commission
- UV disinfection system to kill or inactivate pathogens.

Treated effluent is discharged to soil soakage galleries.

Scheme Construction

A Maldivian contractor was employed to build the sewerage scheme with an expatriate supervisor to provide guidance and monitor progress. Generally construction progressed well with the major challenge being the combined pumping well and recirculation chambers because much of it was below groundwater level. Mechanical digging equipment was limited to one back actor. All concrete was mixed on site and placed using wheel barrows or buckets.

Scheme Commissioning

Commissioning was carried out both to check the system operation prior to making connections and to educate local staff. It involved:

- inspecting all septic tanks that would connect to the scheme and identifying any work necessary, such as pumping out, insertion of inlet and outlet tees, and sealing of the soak pit connection pit
- carrying out draw down tests to calibrate pumps using one, two and three filters and preparing a timer schedule for different effluent inflows
- inspecting discharge jets in the recirculating granular medium filters.

The project provided a trailer mounted vacuum tanker and tractor for septic tank desludging. This equipment was used to clean all septic tanks that had excess sludge.

Scheme Performance

To date the effluent treatment system has performed well mechanically and electrically. However, during the wet season there was considerable inflow, which resulted in higher

than design flows at times. As a consequence, the timer had to be readjusted on occasions to increase the daily effluent through flow.

Scheme operation is carried out by local staff with supervision by an engineer based in Male. Liaison with the design team has been maintained. All parties have benefited through the continued communication.

Summary

The Maldives is tropical, multi-island state. The islands are all atolls, rising only to about one metre above high tide level, and have fragile fresh water lenses that provide water for the island residents. Contamination of these lenses by solid waste leachate and human waste discharges is of concern. A component of the Government's first regional development project was to identify and to implement solid waste management solutions and a pilot sewage management solution for the selected, project islands. A project objective was to propose low cost and low technology solutions that could, if successful, be replicated elsewhere in the Maldives.

The solid waste solution is a waste management site that receives waste separated as general municipal waste, greenwaste, recyclables and hazardous waste. General waste is disposed of to an unlined, engineered landfill, greenwaste is shredded for waste cover material, recyclables are sorted and baled for export and hazardous waste is stored securely for export. A key component was selecting waste management sites that minimised the risk of contaminating groundwater used for water supply and received the approval of the communities.

The human waste solution is a pilot sewerage scheme comprising the collection of septic tank effluent by small diameter sewerage and effluent treatment by a re-circulating granular medium filter and ultra violet disinfection, and discharge to ground.

The waste management sites and the pilot sewerage scheme were commissioned in 2003. Commissioning included the training of the personnel responsible for the operation of the new facilities.

The performances of the waste management sites and the pilot scheme are being monitored and a review mission by the project team is scheduled for early in 2004.

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