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Sustainable Approaches for Materials Management in Remote, Economically Challenged Areas of the Pacific

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National Risk Management Research Laboratory
Land Remediation and Pollution Control Division

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Sustainable Approaches for Materials Management in Remote, Economically Challenged Areas of the Pacific

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Notice/Disclaimer

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Foreword

The U.S. Environmental Protection Agency (US EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, US EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) within the Office of Research and Development (ORD) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

Cynthia Sonich-Mullin, Director
National Risk Management Research Laboratory

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Acronyms and Abbreviations

ACI	Air curtain incinerators
ASEPA	American Samoa Environmental Protection Agency
ASPA	American Samoa Power Authority
BECQ	Bureau of Environmental and Coastal Quality
BMP	Best Management Practices
BOS	Batch Oxidation System
CFR	Code of Federal Regulations
CNMI	Commonwealth of Northern Mariana Islands
DPW	Department of Public Works
EPA	Environmental Protection Agency
FML	Flexible membrane liner
HHW	Household hazardous waste
LCRS	Leachate collection and removal system
MSW	Municipal Solid Waste
NREL	National Renewable Energy Laboratory
NRMRL	National Risk Management Research Laboratory
PPA	Power Purchase Agreement
RARE	Regional Applied Research Efforts
RFP	Request for Proposals
RFQ	Request for Qualifications
RCRA	Resource Conservation and Recovery Act
SPREP	Secretariat of the Pacific Regional Environment Programme
ISWM	Integrated Solid Waste Management
TOS	Thermal Oxidation System
UNEP	United Nations Environmental Programme
US	United States
US EPA	United States Environmental Protection Agency
WTE	Waste to Energy

Executive Summary

Remote, economically challenged areas in the Commonwealth of the Northern Marianas Islands (CNMI) and American Samoa in the US Pacific island territories face unique challenges with respect to solid waste management. These islands are remote and isolated, with some islands supporting only small populations, thus limiting options for pooling resources among communities in the form of regional waste management facilities, as is common on the US mainland. This isolation also results in greater costs for waste management compared to those encountered in the mainland US, a consequence of, among other factors, more expensive construction and maintenance costs because of the necessary transport of facility components (e.g., landfill liner materials) and the decreased attractiveness of waste recovery for recycling because of lower commodity prices after off-island transportation. Adding to these economic limitations, the gross domestic product and per capita income of the Pacific territories is less than half what it is in parts of the US.

The first section of this report outlines a snapshot of the current state of solid waste management overall in the US Pacific island territories, primarily based on site visits. Steps involved in this work included a review of selected existing published information related to the subject; site visits to Guam, Saipan, Tinian, Rota, Tutuila, and Apia; and an assessment of the technical and economic feasibility of different solid waste management technologies for remote, economically challenged areas in the US Pacific island territories.

Landfills designed to meet the minimum criteria for municipal solid waste landfills at 40 CFR Part 258 (herein referred to as Subtitle D requirements) are currently operated on Guam and Saipan. Waste disposal on the other islands (including Tinian, Rota, Tutuila, Aunu'u, Tau, Ofu, and Olosega) occurs through some form of unlined landfilling or open dumping or off-island transport of wastes. Site visits to Tinian and Rota found that the local government authorities maintained disposal sites at distinct locations and that these facilities were being upgraded from open dumping to more controlled sanitary landfills. The America Samoa Public Works Authority currently employs sanitary landfill practices at the Tutuila disposal facility, including waste compaction and cover soil placement.

A preferred waste management solution is one focused on waste reduction and enhanced materials recovery through recycling and energy recovery. A number of recycling operations were observed during the site visits, particularly on the larger islands, with metals being the most commonly recycled material. Discussions with government officials and a review of existing information found that construction of waste-to-energy facilities had been considered on a number of occasions, but may not be economically viable, and/or are prohibited by local law.

The second part of the document provides guidance to remote, economically challenged areas in the US Pacific island territories (and other similar locations) focused on management practices that promote sustainable materials management and minimize risk to human health and the environment. The information presented was derived from current waste-management practices along with experience gathered from waste-management practices from isolated communities outside the continental US.

The environmental and human health risks posed by improperly managed solid wastes are described. Fundamentals, such as understanding local waste characteristics, opportunities for waste reduction, and waste collection are reviewed. Recycling can be more challenging in remote, economically challenged locations because transportation costs often outweigh recoverable market value. High community participation rates and sufficient storage capacity for stockpiling materials are essential features of a successful program that recycles large quantities of materials at rates comparable to the US mainland. Source-segregating and biological treatment of organics by composting or anaerobic digestion provide a landfill diversion step not generally limited by transport distances. Both organic treatment methods produce a residual which can be beneficially used, with an added benefit of anaerobic digestion involving the production of gas usable for fuel. Energy recovery from waste through traditional thermal treatment methods will, in most cases, not be feasible because of the small amount of wastes produced and the high capital costs of these technologies.

A number of design and operational approaches are required to reduce environmental impacts from landfills. (Please see 40 CFR 258 for the minimum federal criteria for municipal solid waste landfills.) Site location is critical to avoid sources of drinking water and sensitive environments. Waste compaction, cover soil placement, and proper configuration of the landfill disposal area help minimize issues such as fires, odors, and disease vectors, and can reduce the potential for off-site migration of pollutants from leachate and landfill gas. Landfill gas problems can be reduced through implementation of good cover soil practices and installation of gas vents constructed with locally available materials. Lined MSW landfilling capacity can be preserved by the construction of non-municipal landfills accepting only certain non-hazardous, non-municipal waste materials, operating in compliance with 40 CFR 257, and by sustainable management practices that divert certain materials from the disposal waste stream. For areas seeking to adopt compliant alternative waste management technologies, contract development issues are also discussed.

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1. Introduction

1.1. Background and Objectives

Local governments have the responsibility of providing solid waste management services for their residents. Elements of a modern integrated solid waste management (ISWM) system include collection, transport, resource recovery, and disposal of waste. Challenges associated with planning and implementing any ISWM system include (1) providing services that meet residential, commercial, and institutional needs in an economically feasible manner, and (2) utilizing technologies that meet regulatory requirements and best protect human health and the environment. The disposal of solid waste in the US, which is governed by the Resource Conservation and Recovery Act (RCRA) Subtitle D landfill regulations (40 CFR 258, herein referred to as Subtitle D), require that landfilled municipal solid waste (MSW) be disposed of in lined, solid waste management units that meet *minimum* federal criteria for location, design, operation, and monitoring criteria. Open MSW dumps are prohibited under RCRA. As for the disposal of non-municipal wastes, sanitary landfills meeting the requirements of 40 CFR 257 have been utilized, along with sustainable materials management methods, to preserve subtitle D MSW landfill capacity for MSW. It is noteworthy to mention that this report focuses primarily on MSW disposal in remote, economically challenged areas in CNMI and American Samoa in the US Pacific territories.

Guam, the Commonwealth of Northern Mariana Islands (CNMI), and American Samoa are three US territories in the Pacific visited for this research project. Guam was visited to gather background information while materials management practices were examined in more detail in CNMI and American Samoa. Within CNMI and American Samoa are a number of isolated communities with relatively small populations. The US Environmental Protection Agency (EPA) is invested in improving solid waste management in these communities, a particular challenge because of their isolated location, small population size, significant seasonal fluctuations in waste generation (due to tourism) and limited land available for development. These communities also tend to be economically disadvantaged, lacking the funds (as well as access to advantageous financing options), and technical expertise to develop, operate, and maintain integrated solid waste management systems. Island nations where these remote, economically challenged areas are located, are also vulnerable to extreme weather events, and the typical location of most island landfills, in flat coastal areas, further increases exposure to storms, and thus, the potential for dispersion of solid waste into the aquatic environment from unsecured coastal landfills is a real possibility (Eckelman et al. 2014). In 2014, US EPA Region 9 applied for and was awarded a Regional Applied Research Efforts (RARE) project to provide technical assistance on solid waste management for remote, economically challenged communities in CNMI and American Samoa in the US Pacific territories.

1.2. Report Organization

This report is organized into seven sections. Section 2 describes the challenges faced by remote, economically challenged communities in managing their wastes. Section 3 outlines the site visits and presents field observation. Section 4 describes the importance of proper waste management and the consequences of inadequate waste management. Section 5 discusses the fundamentals of integrated solid waste management, including details on waste characterizations, methods of waste reduction, and waste collection. Section 4 discusses resource-recovery methods, including recycling, organic material recovery through composting and anaerobic digestion, and energy recovery from the thermal treatment of materials. Section 6 provides an overview of resource recovery and recycling. Section 7 consists of a detailed discussion of combustion technologies and landfilling, considered methods of waste disposal. Section 8 describes different types of hazardous and special wastes that communities typically encounter, including medical waste, household hazardous waste, e-waste, batteries, and other materials. Section 9 discusses recommendations for contracting for new solid waste technologies. Section 10provides the report references.

1.3. Quality Assurance and Control Plan

This project entailed the collection and analysis of secondary data. The appropriateness of the data and their intended use was assessed with respect to data source, data collection timeframe, and the waste management facility capacity or the community size that the data represent. The highest preference was given to materials management program-specific data/information collected through interviews with US Pacific islands territories community decision-makers. For other sources, preference was given to data from well-developed, peer-reviewed reports/papers (e.g., those published in government reports and peer-reviewed journals) over information that had not undergone a peer review process (e.g., conference proceedings, trade journal articles, personal estimates). Data from communities of a size representative of the small communities in the US Pacific island territories were preferred over those representative of larger-sized communities. Preference was given to more recent data over older data. The report includes the sources of all data and identifies any data limitations.

2. Background

2.1. The US Pacific Islands Territories

The focus of this report is remote, economically challenged areas in CNMI and American Samoa, which were visited as part of this research. Although Guam is not a focus of this study, Guam was visited for purposes of obtaining an overview snapshot of Guam's solid waste management. Guam demographics and other statistics are provided for informational purposes relative to the focus areas of the report.

The islands are a great distance from the US mainland (e.g., American Samoa is closer to New Zealand, and Guam and the CNMI are closer to Asia than to the US) and have a much smaller population and size compared to most US states. Guam is a single island with a land mass of approximately 211 square miles; the CNMI and American Samoa consist of smaller land masses comprised of multiple islands.

Table 1 provides basic demographics of the territories, including a list of the primary islands, their land area, and their populations compared to the US mainland. Of the islands visited, Guam is the largest island and most populated. The next were American Samoa and CNMI, Tutuila and Saipan, respectively, which are comparable in size and population. While the larger islands of Guam, Tutuila, and Saipan have relatively large population densities, many of the smaller islands are much less densely populated.

Table 1. US Pacific Island Territory land area, population and Population density

Territory	Island	Approximate Area (mi^2)	Population[a] (2010)	Population Density (People/mi^2)
Guam	**Guam**	**211[b]**	**159,358**	**760**
American Samoa	**AS Total**	**76.14**	**55,519**	**726**
	Tutuila	53[c]	53,770	1,015
	Aunu'u	0.59[c]	589[d]	998
	Ofu	2.79[c]	176	63
	Olosega	1.99[c]	177	89
	Ta'ū	17.11[c]	790	46
	Swains Island	0.58[c]	17	29
	Rose Island	0.08[c]	0	0
CNMI	**CNMI Total**	**179.15**	**53,883**	**296**
	Saipan	48[e]	48,220	1,005
	Rota	33[f]	2,527	77
	Tinian	39.2[g]	3,136	80
	Northern Islands	58.95[h]	0	0
United States mainland		**3,531,905[i]**	**318,857,056[i]**	**87[i]**

[a]US Census Bureau (2011a, b, c)
[b]Gingerich (2013)
[c]US Census Bureau (2003)
[d]Population was estimated by using US Census 2000 percent of Sa'ole county designated as Aunu'u village and applying the same percentage to the US Census 2010 for Sa'ole county.
[e]Carruth (2003)
[f]Carruth (1999)

[g]Gingerich (2002)
[h]Based on subtracting the other CNMI islands from the total land area estimated by (CIA nd.c).
[i]US Census Bureau (2015a), population data is from 2014

Table 2 compares the economies of the US Pacific island territories to that of the US mainland. The per capita income is much greater for the US mainland than for the island regions (nearly two times larger than Guam and more than four times greater than American Samoa and CNMI). Median household incomes are similar between Guam and the US mainland, but American Samoa and CNMI are less than half that of the US mainland. The economic disparity between the US mainland and American Samoa and CNMI is further demonstrated when comparing poverty rates; these two US Pacific island territories have nearly four times the percentage of residents living below the poverty line than does the mainland US (US Census Bureau 2011b, 2011c and 2015b).

Table 2. US Pacific Islands Territory economic data

Territory	2013 GDP (million dollars)	Per Capita Income (GDP/Population)	2009 Median Household Income
Guam	$4,882[a]	$30,635	$48,274[e]
American Samoa	$711[b]	$12,806	$23,892[f]
CNMI	$682[c]	$12,657	$19,958[g]
United States mainland	$17,078,300[d]	$56,185	$50,221[h]

[a]BEA 2014a
[b]BEA 2014b
[c]BEA 2014c
[d]BEA 2014d
[e]U.S. Census Bureau (2011a)
[f]U.S. Census Bureau (2011b)
[g]U.S. Census Bureau (2011c)
[h]U.S. Census Bureau (2015b)

2.1.1. Guam

Guam is a single-island territory in the North Pacific Ocean, approximately three-quarters of the way from Hawaii to the Philippines. As previously described, Guam is the largest and most populous of the three US Pacific island territories; Guam has a residential population around 159,000. The population of Guam consists of a broad range of ethnicities, with Chamorro and Filipino being most prominent. English is the predominant language; however, a variety of other languages are spoken. Hagåtña is the capital of Guam, the location of which can be seen in Figure 1. Average temperatures in Guam range from about 75-90°F throughout the day, and the annual rate of precipitation typically ranges from approximately 80-120 inches (NAOO 2014).

In addition to being the largest, most populous of the pacific territories, Guam also has the strongest economy. The gross domestic product (GDP) for Guam was 4.9 billion dollars in 2013. As the island houses a strategic US military base, Guam's economy relies heavily on US national defense spending. Tourism is the next most important source of income for the island. The unemployment rate in Guam is 8%, and the percent of the population living below poverty is about 22%. Guam is predominately dependent on fossil fuels for its energy demands; however, the territory is expanding and exploring other alternative fuel sources. The island has four airports with paved runways and one major sea harbor, Apra Harbor (CIA nd.a).

In Guam, solid waste management is primarily under federal Receivership, and much of the solid waste infrastructure is under federal litigation and, therefore, not the subject of this report. The Receiver was not interviewed for purposes of this report. Consequently, discussion is limited to some basic published information to help provide a snapshot of solid waste management in Guam. For more information, the reader is directed to the Receiver's website at www.guamsolidwastereceiver.org. Nothing in this report should be construed as a federal position on the litigation or the work being performed under the federal Consent Decree.

The relatively newly constructed Layon Municipal Solid Waste Landfill (MSWLF), compliant with Subtitle D requirements, began accepting waste in September 2011, coinciding with the Ordot dump ceasing waste acceptance. The Layon MSWLF has an estimated design capacity of 15.8 million cubic yards and approximately 127 acres. The published tipping fee for commercial haulers ranges from $156/ton for customers in good standing to $171.60/ton. The cost for household curbside collection is $30 per month for the first 96-gallon bin and an additional $15 for a second bin (DCG 2014, GSWA 2015), and includes curbside single stream recycling bin for paper, cardboard, metal, plastic, and aluminum. Residents may also drop off household hazardous waste at the Household Hazardous Waste (HHW) facility in Harmon at no charge.

Figure 1. Map of Guam (Google Earth August 2016)

2.1.2. The Commonwealth of the Northern Mariana Islands

The Commonwealth of the Northern Mariana Islands (CNMI) is just north of Guam and consists of a three-hundred-mile archipelago that includes 14 islands, with a total land area of approximately 180 square miles. The average annual temperature for CNMI ranges during the day from 75 to 88°F with an annual rainfall of about 83 inches. CNMI has a population of 53,900, with a majority of inhabitants living on the islands of Saipan, Rota, and Tinian (Figure 2). Saipan is the capital of CNMI, and approximately 90% of the population resides here. Figure 2 is a map of CNMI in which the three most important islands can be identified. The population of CNMI is comprised of a range of ethnicities, primarily people of Asian or Pacific Islander decent. The official languages of the territory are Chamorro, Carolinian and English; however, Tagalog is commonly spoken (CIA nd.c).

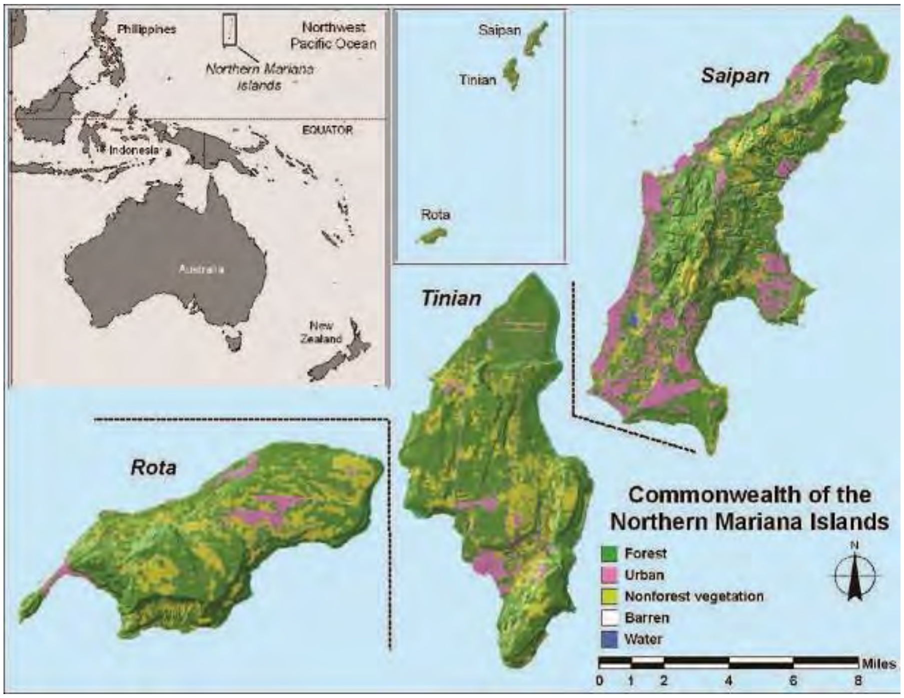

Figure 2. The main islands of the commonwealth of the Northern Mariana Islands: Saipan, Tinian and Rota (Google Earth August 2016)

The four municipalities of CNMI are Saipan, Tinian, Rota, and the Northern Islands. The US Legal system applies in CNMI, with the exception of customs, wage, immigration, and taxation laws. CNMI's economy benefits greatly from the assistance of the US; 80% of funds for the construction of the Marpi Landfill were provided under the CIP of the Office of Insular affairs from the Department of the Interior (the same source of funds used for closure of the Puerto Rico Dump in Saipan), with the remaining 20% provided by CNMI (Leavitt 2005). The primary industries of CNMI are tourism, banking, construction, fishing, handicrafts, and other services; the tourism industry accounts for approximately 25% of the employment and GDP. CNMI's GDP in 2013 was $682 million, the lowest of the three territories (BEA 2014c). The unemployment rate for CNMI is estimated at 11%, and the percentage of people living below poverty is about 52% (US Census Bureau 2011c). The territory is home to three airports with paved runways, one heliport, and major seaports on Saipan, Tinian, and Rota (CIA nd.c).

CNMI is an approved state under RCRA Subtitle D and issues permits to solid waste facilities. Currently, the Marpi landfill in Saipan is the only landfill in CNMI designed to be RCRA Subtitle D compliant, the site visit to which is discussed in Section 3.3.1. The Marpi landfill opened in February 2003 and according to a January 24, 2005 article in the Saipan Tribune, it cost approximately $20 million to construct (Saipan Tribune 2005). Saipan also has a transfer station and a co-located recycling facility. Tinian and Rota each operate their own open dump; these facilities have been confronted with issues such as odors and fires, and they are under administrative orders to improve conditions. A waste characterization study was completed by Allied Federated Energy in 2011 as part of an effort to implement a plasma gasification WTE facility. To date, no agreements have been reached with regard to the construction of any WTE facility.

Currently, construction of a large-scale resort and casino (over 4,000 hotel rooms) is planned for Saipan, with the first phase scheduled for completion in late 2016 and the final phase of construction scheduled for 2022 (Cohen 2015). The additional waste generation from these construction activities will cause an increased burden on the existing Marpi landfill. The assessment of impact fees associated with new development may provide a future opportunity to obtain funds to assist with solid waste infrastructure costs related to increase waste generation from construction activities and attraction of greater population to the island. Many municipalities and governments utilize impact fees (specific to solid waste but also commonly assessed for other infrastructure needs, e.g., fire rescue and correctional facilities) for new development (e.g., based on building permits issued) to offset the added support burdens associated with development.

A proposed US CNMI joint military training (CJMT) area (live-fire ranges) is tentatively planned for construction on the island of Tinian, as reported in a draft document, though no final decisions have been made. The proposed facility would accommodate a maximum of 3,095 personnel (only 95 year-round permanent employees, 850 average) (NAVFAC 20km , 15). Expected waste generation as a result of these activities is approximately 534 tons per year (not including an assumed diversion rate of 55% based on data from Guam military bases), assuming a 20-week period of live-fire training yearly though it was reported that training frequency may increase to up to 45 weeks of live-fire training annually, thus expected waste generation would increase to more than double (NAVFAC 2015). The tentative plan is for the military to construct a transfer station for packaging of collected waste generated at CJMT, as well as sorting and packaging of recyclables, into shipping containers for transit to the Port of Tinian and then to the Marpi landfill facility on Saipan through barge transport (either through a dedicated barge for CJMT wastes or contracted through a third party operator) (NAVFAC 2015). Details related to operation and conditions at the Marpi Landfill are discussed in Section 3.3.1. Costs for construction and operation of the transfer station were estimated at approximately $4.0 million and $768,000/yr, respectively (NAVFAC 2015). Green waste generated as part of CJMT operations is anticipated to be mulched, and land applied on site (NAVFAC 2015).

Because DOD facilities are not permitted to dispose of waste in facilities which are not compliant with Federal RCRA Subtitle D regulations, the Tinian Municipal Open Disposal site would thus not suffice as a waste management option. Development of Cell 3 at the Marpi landfill is required to provide a continued and assured location for legal disposal of waste from CJMT activities; a proposed timeline including 12 months for design and permitting, 4 months for construction bidding and 8 to 10 months for cell construction (NAVFAC 2015). It was also recommended that Cells 4 to 6 be designed concurrently with the design of Cell 3 for economic reasons (NAVFAC 2015). Capital Improvement Program (CIP) funds are being used to construct a new transfer station on Tinian for transport of wastes to the Marpi Landfill on Saipan (Chan 2015).

The capacity of the Marpi landfill is being utilized at an increased rate from previous years due to both developments on the island, as well as Typhoon Soudelor, a storm which affected the island in August 2015. The storm was severe enough to prompt authorization of FEMA assistance under a major disaster declaration. As a result of the storm, solid waste received at the Marpi landfill increased by 64% for the August through December 2015 period, up to 81.88 TPD over the waste acceptance rate of 64.42 TPD based on operation during the same time period during 2014. It should also be noted that waste acceptance in 2014 was up from the 49.67 TPD accepted in 2012. CNMI's population is estimated to increase by 10,000 (from 2016) due to worker populations corresponding to hotel development by 2019. The two cells present at the Marpi site may be filled to capacity within a period of approximately five years due to increased waste disposal resulting from development on CNMI (Chan 2016).

2.1.3. American Samoa

American Samoa consists of a group of five volcanic islands (Tutuila, Ofu, Olosega, Tau, and Aunu'u) and two coral atolls (Rose Island and Swains Island) located halfway between Hawaii and New Zealand, to the southeast of Guam and CNMI. The total land mass of American Samoa is approximately 76 square miles; it is the smallest of the US Pacific island territories. The capital city of American Samoa is Pago Pago on the isle of Tutuila, the largest and most populated (over 95% of the population resides on the island) of the American Samoan islands (Figure 3). Pago Pago has one of the best natural deep-water harbors in the South Pacific because it is sheltered from rough seas and protected by the mountains from high winds. The average annual temperature in American Samoa ranges from 70-90°F, and an average annual rainfall at Pago Pago Airport is about 120 inches (Keener et al. 2013).

Figure 3. Map of American Samoa islands

The population of American Samoa is approximately 55,500 people. Over 90% of the population speaks Samoan, and most residents are bilingual. American Samoa contains three districts – Eastern, Manu'a, and Western - and two islands - Rose Island and Swains Island. The legal system in American Samoa is mixed, with aspects of US common law and customary law (CIA nd.b).

American Samoa has a traditional Polynesian economy in which more than 90% of the land is communally owned. The American Samoa GDP was estimated at approximately $711 million in 2013 (BEA 2014c). Economic activity is strongly linked to the US, American Samoa's primary trading partner. Tuna fishing and tuna processing plants represent the primary industry, supporting 80% of the territory's employment. In late September 2009, an earthquake and resulting tsunami devastated American Samoa, disrupting transportation and power generation and resulting in about 200 deaths. The US Federal Emergency Management Agency (FEMA) oversaw a nearly $25 million relief program. Although tourism is a promising sector for the economy, the remote location, limited transportation, and potential tropical cyclones have hindered attempts by the government to expand the economy (CIA nd.c). As of 2005, unemployment was high, at 29.8%, and the percentage of people living below the poverty line was approximately 57% in 2009 (US Census Bureau 2011c). In terms of international access, American Samoa has three airports with paved runways (CIA nd.c).

American Samoa does not have an RCRA Subtitle D state-approved program and the territory has one unlined disposal facility (Futiga solid waste facility) on Tutuila that implements fundamental sanitary landfill practices (e.g., cover soil, compaction). The facility was anticipated to reach capacity in 2015 (Conrad et al. 2013). Solid waste collection and operation of the Futiga solid waste facility are provided by the American Samoa Power Authority (ASPA). Waste collection and disposal on the other islands is also provided by ASPA. As part of a WTE facility feasibility study for American Samoa, SCS Engineers (2009) conducted a waste characterization study at the Futiga solid waste facility in 2009. Over 27% of the waste resulted from residential sources, with the rest produced by commercial sources. Tables 3 present the material composition of the waste. Paper and organics comprised the most significant portion of waste sent to the Futiga solid waste facility and were estimated to comprise nearly 50% of the waste stream (Table 3). Cardboard and kraft paper (19.1%) followed by ferrous cans (16%) were the two specific materials found in greatest mass. The SCS study also estimated the heating value for the waste as 2,900 BTU/lb excluding tires and waste oil and 4,060 BTU/lb including these components. American Samoa is currently pursuing a waste conversion project that would utilize the combustible portions of waste to produce electricity. The total waste disposed of annually at the Futiga solid waste facility was estimated to be 20,960 tons (SCS 2009); the actual measured annual tonnages of material disposed at the landfill over the past four years has increased from 21,000 tons in 2011 to 28,000 tons in 2014 (ASPA 2015).

Table 3. 2009 Futiga solid waste facility waste material characterization (by mass) conducted by SCS (2009)

Material	%
Paper	26.4
Glass	3.4
Metal	7.9
Plastic	12.8
Organics	19.6
Textiles	4.2
Construction and Demolition	2.8
Hazardous	0
Special	6.8
Mixed Residue	16.0

3. Site Visits

3.1. Trip Timeline and Objectives

One aspect of this project included site visits to obtain a snapshot of solid waste management in the overall Pacific Island territories, including Guam. Two site visits were conducted over the course of the study. The first visit took place between September 14-19th 2014 and included visits to Guam and CNMI (Saipan, Tinian, Rota). The second site visit was conducted from January 26-30th 2015 and included visits to the territory of American Samoa (Tutuila) and the country of Samoa (the latter is not part of the U.S. Pacific Island territories). Although solid waste management on Guam is comparable to that on the US mainland (high recycling rate, federally compliant MSWLF and operations), Guam is included here only for completeness and informational purposes. This section of the report summarizes the site visits; photographs are included.

3.2. Guam

As noted earlier, solid waste management in Guam is primarily under federal Receivership, and much of the solid waste infrastructure is under federal litigation and, therefore, not the subject of this report. The Receiver was not interviewed for purposes of this report. For more information, the reader is directed to the Receiver's website at www.guamsolidwastereceiver.org. Nothing in this report should be construed as a federal position on the litigation or the work being performed under the federal Consent Decree.

Preliminary activities after arrival in Guam included a drive-by visit to the Agat residential transfer station on the west side of Highway 2. Agat is one of four residential transfer stations in Guam (one of the transfer stations is now closed pursuant to the decision of the Guam EPA Administrator). The Agat transfer station consists of an elevated tipping area for disposal into a roll-off box and a separate container for cardboard. Later conversations with waste professionals on Guam suggested that this type of facility is similar to other transfer stations. Upgrades to the transfer stations are being completed by the federal Receiver.

A meeting was held with Guam EPA to among other things, discuss the current status of the landfills on the island. As noted earlier, under the federal Receiver, the Ordot dump stopped accepting waste in 2011, and the physical closure work was completed in early 2016. The Layon MSWLF opened in 2011 and, in response to public concern, was designed with a liner system that includes redundant protection from potential release of leachate. Guam is a positive example of how a territory which once only had a large unlined landfill as the sole option for MSW disposal can design, construct, and operate a state-of-the-art MSWLF. The Layon MSWLF commercial tipping fee and residential rate are noted in Section 2.1.1. Residents have the option to subscribe to curbside service for trash and recyclables. There are also three residential transfer stations for disposal of residential trash and recyclables. Residents may also drop off household hazardous waste at the Household Hazardous Waste (HHW) facility in Harmon at no charge. This state-of-the art HHW facility provides for the safe disposal of HHW and is the first of its kind in the U.S. Pacific Islands territories.

During the meeting, Guam EPA noted several locations where illegal dumping was known to occur (Figure 4 illustrates observed waste dumped in some of these locations). The dumping areas that were visited were along utility corridors; some areas were labeled with signs to discourage dumping garbage. A large number of television sets were observed, and the waste appeared to be from local businesses. It is not known when the dumping occurred or how long the dumped items had been there.

Figure 4. Observed waste along utility corridor in Guam

3.3. The commonwealth of the Norther Mariana Islands

3.3.1. Saipan

The CNMI visit began on Saipan. A meeting was held with the CNMI Bureau of Environmental & Coastal Quality (BECQ), the CNMI environmental regulatory agency). A quick overview of the RARE project was provided to BECQ. BECQ gave an overview of the issues they are having with the dumps on Tinian and Rota. In a subsequent meeting with BECQ, the Department of Public Works (DPW), APEC (the consultant contracted to perform groundwater sampling at the Marpi landfill), and Tang Corp (the firm contracted to operate the Marpi landfill), the RARE project was introduced to the meeting attendees. DPW provided copies of budget information with regard to solid waste funds for Saipan, Tinian, and Rota and the operational checklist for the Marpi landfill were reviewed. Following review of the operation procedures required for the Marpi landfill, operational and maintenance challenges were discussed with APEC and Tang Corp. One topic discussed was the purchase of equipment by DPW for use on all three islands, including a wood grinder and earth moving equipment.

EA Engineering provided information regarding the current status of the open dumps on Tinian and Rota in CNMI (they have been contracted to assist with the improvement of these dump sites). Site improvements are being made to the Tinian and Rota dumps based on an Order from BECQ. The site improvements do not involve any liner construction; rather they entail upgrading facility control operations (e.g., controlled access, defined waste disposal areas, etc.) and moving, compacting, and covering existing waste. The improvements also call for the development of a site operations plan. The funds used to conduct this work come from the Construction Improvement Project (CIP) within the DOI Office of Insular Affairs. CIP funds have been allocated for improving the Tinian and Rota Dump sites and for closing the Puerto Rico Dump on Saipan. Equipment has been purchased for each of the sites, including bulldozers and a grinder. More information on each of these locations will be presented in the section describing the site visits.

The Marpi Landfill was designed as a Subtitle D landfill and began operation in February 2003; Figure 5 is an aerial view of the landfill site. The previous disposal facility was the Puerto Rico Dump, which was being closed at the time of the site visit. The Marpi landfill consists of six cells (two are currently lined and the others are planned). In Cell 1, waste was visually observed to cover the majority of the liner system; the peak elevation of landfilled waste reached above the highest elevation of the cell's lined outer perimeter with ample capacity remaining in the cell. The cover soil was observed to be in relatively good condition, though a few leachate seeps were evident from the access road. A small amount of waste appeared to extend over the separation berm between Cell 1 and 2 into Cell 2. Cell 2 is lined in a similar manner to Cell 1, and its bottom was relatively overgrown with vegetation; what appeared to be ponded liquids was also observed in Cell 2. Based on information gathered at the site, waste was not being placed in Cell 2 at the time of the visit because the termination berm between Cell 2 and the currently unlined Cell 3 was inadequate.

Figure 5. Aerial view of the Marpi Landfill in Saipan, CNMI

Cells 1 and 2 are equipped with leachate removal pumps (three pumps per cell); these pumps were reported as inadequate for leachate removal. At the time of the visit, it was observed that the Cell 1 leachate pump station was not operating and had not been operated recently. Reported issues with the pumping system included pipe clogging, a consequence attributed to a leachate collection and removal system (LCRS) drainage material with a high concentration of calcium carbonate ($CaCO_3$) (which can cause deposition of precipitates in the piping system). Issues with pump operation due to a fluctuating diesel power supply were also noted. The pumps for Cell 2 were operating but, apparently, could not keep up with the existing leachate flow rate as evidenced by the ponded liquid in the cell. The BECQ determined the liquid was leachate, but it was reported to be very dilute. The conditions of the pumping system suggest that a significant amount of leachate is built up on the liner system.

The perimeter of Cell 1 (where the waste met the liner system) was observed to be constructed in a manner that caused stormwater runoff intercepted by the landfill to be retained within the cell. This additional water entering Cell 1 likely resulted in a substantial amount of additional leachate. The leachate treatment system was located at the end of the site with the highest elevation, which was noted as a flaw. Leachate treatment at the facility consists of a large lined pond, a series of aeration chambers, and a submerged vegetation bed as presented in Figure 6. After the leachate travels through the submerged vegetation bed, it is pumped to an infiltration basin on the lower end of the site. Issues regarding maintenance of the leachate treatment system were discussed; at least one of the vegetation beds was not being used as designed because a valve was not functioning properly.

Figure 6. Lined leachate pond (left) and wetland leachate treatment system (right)

For waste processing activities, the landfill was equipped with a waste compactor. The waste acceptance amount at the facility was approximately 75 tons per day. Most of the waste is hauled directly to the landfill, with some material sent to the Lower Base Refuse Transfer Station (LBRTS, shown in Figure 7). The LBRTS includes a household hazardous waste facility and is operated by DPW.

Figure 7. Lower Base Refuse Transfer Station (left) recyclable hand sorting at LBRT (right)

A recycling facility is also located at the transfer station; this facility is subsidized by DPW and operated by a private contractor. The biggest challenge for the recycling program was identified as the high shipping costs to transport materials off the island. Costs were cited as ranging from $5,000 - $10,000 per 40-foot container to ship to the market. The workers at the transfer station went to great efforts to improve the quality of the materials they were sending to market (e.g., removing plastic labels and rings from PET bottles) as presented in Figure 7. The facility also recovers and compacts waste tires and, as previously mentioned, collects household hazardous wastes. The cost to build the transfer station, which also includes a green waste processing and storage area as well as full utility connections, was estimated at $4.3 million (Leavitt 2005).

The tipping fee for the Marpi landfill is around $25 per ton, an amount that is reportedly not enough to cover the costs of the $9.4 million facility and its associated infrastructure; the island's beautification tax was reported as providing some additional support. Additionally, residents are permitted to dispose of up to 500 lbs. of refuse at no cost; this alleviates the incentive for open dumping which exists when proper disposal is a more expensive option. The next site-management improvements for the Marpi landfill include plans to construct a diversion berm between Cells 1 and 2 and to construct Cell 3, which will handle the Department of Defense (DOD) generated waste on Tinian, should development of the CJMT occur. Planned Saipan developments (hotel and casino), discussed in Section 2.1.2, will cause added burdens on the Marpi Landfill.

3.3.2. Tinian

A visit was also made to the Tinian dump site. The site is located adjacent to a paved road, and waste is dumped on the west side of the road (the ocean side). Most of the dump site was covered by vegetation such that the extent of waste was not readily visible. The active waste movement took place during the site visit (a bulldozer was pushing waste) as shown in Figure 8. Fencing was put between the dump and the road in a portion of the site. Slight waste smoldering was observed during the site visit. On the side of the paved road opposite the landfill, yard trash was segregated for future grinding; the grinder was reported to be the one purchased as part of CIP funding discussed earlier. No waste was observed during the site visit of an unpaved perimeter road that looped around the west side of the dump.

Figure 8. The Tinian Dump

A meeting was held at the mayor's office to discuss the project and the RARE project was introduced. The mayor's staff expressed an opinion that the dump needed to be closed and a new dump site located. Plans to upgrade the site on Tinain from open dumping to a more controlled sanitary landfill practice were discussed. The staff voiced the opinion that some alternative technology for waste management was desired; the specific example of a waste incinerator was highlighted. The staff suggested that if the military were to purchase an incinerator, they would operate the facility. However, more recently, the tentatively planned course of action, based on a draft feasibility study (no final decisions have been made), is shipment of wastes from the proposed facility on Tinian to Saipan's Marpi landfill, should construction of the proposed facility occur (NAVFAC, 2015). According to a May 8, 2015 article in the Saipan Tribune, the existing dump site is also part of property recently leased by a developer planning a new casino resort (Saipan Tribune 2015).

3.3.3. Rota

A meeting was also held at the mayor's office in Rota, an island where the population is decreasing and currently estimated at less than 2,000 people. The RARE project was introduced, and a discussion on the Rota Dump site followed. The mayor's office understood that the current dump is an issue and that the location of another possible dump site has been considered. The acting mayor expressed a desire to improve Rota's solid waste situation.

At the time, the Rota Dump site had no cover which allowed a significant amount of exposed waste as presented in Figure 9. Materials observed at the dump site included recyclables like aluminum cans. While a designated sign for recyclables was present, garbage dominated the area (Figure 9). Furthermore, household hazardous wastes like oil filters and paint cans were observed, as well as some used electronic waste (Figure 10). While the municipality has placed signs throughout the site to provide guidance on placement of specific items, different wastes were scattered throughout the site. Although the area exhibiting exposed garbage was large, observations at the back of the site indicated that additional waste was present and overgrown with vegetation.

The possible future dump site, a rock quarry, was visited. The team also visited the seaports to evaluate possible waste unloading and shipping options, and other potential sites for waste disposal were assessed. The Rota medical center was visited, and medical waste issues were examined. Currently, the medical center stores red bag waste and sharps for subsequent transport off-island. The medical center reported that it was in the process of obtaining an autoclave for sterilizing the waste.

Figure 9. Garbage at the Rota Dump

Figure 10. Household hazardous waste (left) Used electronic waste (right) at the Rota Dump

3.3.4. American Samoa

The visit to American Samoa took place from January 26, 2015, to January 30, 2015. The first portion of the visit (January 26-28th) included observations of typical waste management practices on the main island of Tutuila; meetings were held with American Samoa Environmental Protection Agency (ASEPA) and ASPA to discuss the RARE project and visit the Futiga solid waste facility and other material processing facilities. During the tour of Tutuila, a strong advertising campaign by the ASEPA related to controlling litter was noted both on billboards and on the radio. An example of the anti-litter campaigning on Tutuila is shown in Figure 11.

Collection practices for residential homes and commercial entities were also observed while visiting Tutuila. Residential homes were provided a single bin that was collected curbside, and commercial entities used standard collection dumpsters. Several areas throughout Tutuila were still observed where some illegal dumping has occurred.

Figure 11. Example of anti-litter public campaign promoted by the American Samoa Environmental

After the preliminary tour of Tutuila, a meeting was held with ASEPA to explain the RARE project, to discuss logistics pertaining to the visit, and to gather initial thoughts on the project. A meeting was then held with ASPA to explain the RARE project and to discuss the current situation related to solid waste management on Tutuila. Discussion included the Futiga solid waste facility and the remaining dump capacity, tipping fees, groundwater monitoring activities, permits, illegal dumping, and future plans for waste–to-energy and ash disposal. After the meeting, the team visited the Futiga solid waste facility with ASPA.

While the Futiga solid waste facility was not equipped with a Subtitle D liner, the operator has integrated basic sanitary landfill practices such as placement of cover soil and compaction of waste (a compactor was operating on site). Workers hand pick aluminum cans from the trash after it was unloaded from the garbage trucks and the salvaged aluminum cans were stored in sacks on site (Figure 12). Tires were also segregated from other waste materials. The outer edge slopes of the Futiga solid waste facility, however, were noted to be steep and greater than the 3:1 observed in most U.S. landfill sites (Figure 13). Also, as shown in Figure 13, an area of ponded liquid was present at the base of the landfill and appeared to be part of a natural drainage system. While no testing was performed, the liquid did, by visual assessment, appear to be impacted by the landfill; a small farming area was observed in close proximity to the ponded liquid.

Figure 12. Separating aluminum cans (left) aluminum can storage (right) at the Futiga solid waste facility

Figure 13. Steep side slopes (left) and leachate ponding (right) observed at the Futiga solid waste facility

On 28 January 2015, the team visited a scrap metal yard that ASPA has been utilizing; this operation was located in an active quarry (Figure 14). While on site, baling of scrap metal was observed, and some collected E-waste materials were also observed. A visit was also made to another recycling operation, T&T recycling, which also is primarily focused on recovering scrap metal. As shown in Figure 15, the aluminum cans that were sorted at the Futiga solid waste facility were sent to the T&T operation. The facility was equipped with a small baler for the aluminum cans; however, most the material being recycled was scrap steel, as shown. The team also examined the local hospital's medical waste treatment system, which included an autoclave and a shredder for treating infectious waste. The sterilized and shredded medical waste was shipped to the Futiga disposal facility.

Figure 14. Metal scrap yard at site of aggregate quarry

Figure 15. Recovered aluminum cans and scrap metal at the T&T recycling facility

As part of the field investigation to American Samoa, a side trip was made to Apia, Samoa, to visit the Tafaigata Landfill in Upolu. Please note that Apia, Samoa, is not part of the U.S. Pacific Island territories. A meeting was held with representatives from Secretariat of the Pacific Regional Environment Programme (SPREP) and Japan International Cooperation Agency (JICA), as well as the operator of the site to discuss the RARE project, the facility, and general US Pacific island territories waste management challenges. Historically, the Tafaigata Landfill was the site of an open dump with odors issues and fires. The dump was later converted to a Fukuoka-style landfill. Figure 16 is an aerial view of the construction of the site, and an aerial view of the completed layout of the landfill is shown in Figure 17. This Fukuoka-method landfill was not designed with a composite liner system (i.e., not compliant with Subtitle D), but was constructed with a compacted soil liner graded to allow gravity drainage of leachate. If this method is to be implemented in the US, there will be the need to install a liner system that is in compliance with the Subtitle D regulation. However, the main leachate collection pipe in the landfill is large in diameter and drains into a lined leachate pond. At the same time, the exit of the leachate collection pipe is exposed to the atmosphere and allows air to enter the landfill to promote waste decomposition (Figure 18). While non-compliant with federal regulations, some elements of the approach used at this facility could be utilized at a Subtitle D compliant landfill with potential benefits in terms of operational costs and long-term performance.

The Fukuoka-style landfill technique is also commonly referred to as a semi-aerobic landfill. Under this concept, the presence of air in the leachate collection system (due to the large diameter pipe and limited waste compaction) fosters aerobic biological activity at the bottom of the landfill, thus providing some leachate treatment that would not otherwise occur. Air entry into the landfill is further facilitated by the addition of vertical “chimneys” through the landfill that allow increased venting, as shown in Figure 19. The leachate is less concentrated than typical anaerobic landfill leachate (because liquids are more rapidly removed from the landfill and treatment occurs within the landfill), and is treated through a series of low maintenance treatment steps before being allowed to discharge; the use of mechanical pumps to move leachate is minimized to reduce maintenance costs.

Figure 16. Historic image showing the construction of the Tafaigata Fukuoka-style Landfill

Figure 17. Historical image indicating the layout of the Tafaigata Fukuoka-style Landfill

Figure 18. Lined leachate pond at the Tafaigata Fukuoka-style Landfill showing a large-diameter leachate pipe entering from the landfill

Figure 19. Vertical air/gas vent at the Tafaigata Fukuoka-style Landfill

On 30 January 2015, another meeting was held with ASEPA, including a site visit to several illegal dumping sites. During the site visits, illegally dumped waste on Tutuila as well as debris aggregated on the shoreline was observed. These areas had recently been cleaned up, and ASEPA described continuing efforts to minimize illegal dumping activities. Solid waste management on Ofu and Olosega were also discussed. ASEPA provided photographs of waste management from each of these islands.

4. The Importance of Proper Waste Management

The potential adverse effects of improperly managed solid waste are numerous. Garbage that is stored for a prolonged time or disposed of without appropriate controls may promote the spread of disease by attracting disease vectors such as rats, flies, and mosquitoes. Disease-carrying organisms are attracted to food scraps, fecal matter, and similar materials in the waste stream, and exposed garbage brings these vectors into closer contact with humans, facilitating possible transmission of infectious agents. When located near a water source, stormwater runoff from waste may also contaminate surface and groundwater that may be used for drinking.

A common practice observed in some remote, economically challenged areas of the Pacific is to open burn trash (in an uncontrolled manner), either at the point of generation or at the dump site (Figure 20). The US EPA warns of the adverse health effects associated with the uncontrolled burning of waste because of the numerous health problems that may result, including respiratory illnesses; nervous system, kidney, or liver damage; and reproductive or developmental disorders (US EPA 2003). In these cases, and in addition to the health issues associated with the smoke generation particulate matter, and harmful chemicals may be released into the air.

Figure 20. Roadside burning of garbage

Another practice that has been observed is the open dumping of MSW. When garbage is dumped on land, the contact of the waste with rainwater, surface water, or groundwater produces a contaminated water source referred to as leachate. If not managed in a controlled manner, leachate can pose a number of human health and environmental concerns. Leachate can contain contaminants resulting from hazardous materials in the waste (e.g., lead, mercury, benzene); these constituents pose a long-term health risk to humans if they are exposed to leachate contaminated water, through pathways such as drinking or bathing. Chemicals produced as a result of decomposing food waste, and paper products are also found in leachate, and these chemicals may harm the ecosystem by reducing oxygen levels in surface water and introducing levels of salts and nutrients that are toxic to many types of aquatic organisms. Without provisions for control, leachate often builds up at the base of dumps and unlined landfills (Figure 21) and may contaminate surrounding water bodies. Furthermore, leachate that mixes with groundwater and/or surface water may travel off site and further contaminate water supplies or reemerge in off-site aquatic environments.

Figure 21. Observed surface water potentially polluted with landfill leachate

Another concern with the open dumps seen at some locations are the gasses generated as a result of the anaerobic decomposition process. When garbage decomposes, the majority of the gas produced is methane and carbon dioxide along with smaller amounts of organic and sulfur compounds. Methane, is flammable; when mixed with the proper quantity of oxygen, methane may become explosive. Thus, fires can become a concern at these sites not only because of explosive gasses but also with the combustible materials inherently present in the waste. When emitted, these gases can also pose a nuisance (e.g., odor) or exposure concerns. These compounds can range from those that can cause odor issues to those that are toxic to human health and the environment. Finally, when waste is placed in steep, elevated piles at large dump sites, the slope of these piles can fail and potentially injure or kill those in the path of the sliding waste.

Consequences beyond direct human health risks from improper waste management methods also motivate the implementation of appropriate ISWM systems. As presented earlier, garbage disposed of in drainage canals or litter that washes into the waterways can promote the breeding of disease vectors by clogging drainage canals which result in standing, stagnant water. Stagnant water conditions also encourage mosquito breeding, producing subsequent resultant human health problems. In addition, litter can reduce the property value and tourism potential of contaminated lands. Even though littered materials may be washed away after a storm, it is very likely that some material will be washed back ashore in a different location (Figure 22). Wastes that enter the oceans are increasingly recognized as a threat to marine wildlife and ecosystems, all of which have a direct economic benefit, especially to island communities.

Figure 22. Plastic wastes observed on the beach of an island community

Thus, local communities should implement policies, such as an ISWM plan, and enforce waste regulations, such as the Subtitle D landfill rules, that are designed to minimize the negative consequences associated with solid waste management. Most of the practices needed to keep garbage from posing a health risk are addressed as part of providing systems for collection, transport, resource recovery, and disposal; these are the subjects of the remaining sections of this report. However, one important element of a successful ISWM system that cannot be addressed by infrastructure and technology is public participation. The generators of the waste, community residents, and businesses, are integral in ensuring that discarded materials are deposited in the appropriate waste container or management location and not indiscriminately dumped. In some communities, movement away from long-standing, status quo waste management practice is challenging. To facilitate this, municipal and regulatory agencies can play a role in promoting positive participation in the community's ISWM system (Figure 11).

5. Integrated Solid Waste Management System Fundamentals

Prior to the discussion of options related to waste recycling, energy recovery, and disposal, several fundamental concepts concerning solid waste management must first be discussed. One step essential to developing an ISWM system (and associated goals with respect to waste reduction and landfill diversion) is understanding the waste stream in terms of waste composition and generation rate (waste characterization). An element of ISWM planning neglected in many cases is the promotion of waste reduction. Another critical feature of solid waste management infrastructure is the system for collecting discarded materials from their point of origin and transporting them to the appropriate facility. These three aspects are described further in this section.

The ISWM system may contain provisions for solid waste infrastructure funding by an assessment of impact fees on development (e.g., hotels, military installations) expected to cause or actively causing increased burdens on such infrastructure. In CNMI planned development includes hotels and casinos on Saipan (after the legislature passed a casino bill in early 2015) and potential military training facilities to be constructed on Tinian (Cohen 2015, NAVFAC 2015). Waste generated on Saipan and Tinian is expected to be taken to the Marpi landfill on Saipan (NAVFAC 2015). Waste quantities deposited in the Marpi landfill increased by 29.7% from 2012 to 2014, increasing the burden on the landfill's operation. Baring-Gould et al. (2011) estimated that the tipping fee for the Marpi landfill would need to be increased to cover the real costs of landfill operation, as current tip fees charged are insufficient to do so.

5.1. Waste characterization

The US EPA estimates that on average approximately 4.4 lb of MSW is produced per person every day in the US and that the largest components of the waste stream are paper products, yard trash, food waste, and plastics products (US EPA 2015a). While these numbers may be sufficient to develop a general understanding of the waste stream, waste composition and generation vary by region as a result of a number of factors. Given the significantly different set of conditions on these islands, it is useful to gather location-specific waste data. Production amounts can be determined from existing waste collection data if available. Methodologies have been developed for conducting site-specific waste composition studies (US EPA 2015b). Figure 24, for example, shows the results of a waste characterization study conducted for American Samoa (SCS Engineers 2009); this study was done by examining disposed waste at the community site; 27.7% of the total waste mass was generated in residential areas while 72.3% came from commercial sources.

Waste-composition study results are useful for a number of reasons. Materials that can be prioritized for waste reduction and recycling can be identified. Estimates of the volume of biodegradable materials (e.g., food waste, paper products) present provide valuable information when assessing the potential for source-segregated organics composting and anaerobic digestion, as well as estimating quantity and composition of the gas produced at a landfill after disposal. In addition, problem items that could pose hazards to human health and the environment can be identified. While a waste composition study can be a relatively large effort that takes place over multiple weeks and several seasons, procedures for more rapid studies in developing countries, have been recommended (Krause and Townsend 2014). The waste composition can change over time, depending on industries present in the areas studied. Thus, it is important to update waste composition studies periodically (e.g., the decline of the garment industry in Saipan caused a decrease in garment factory related waste from 33% to 6%) (Leavitt 2005).

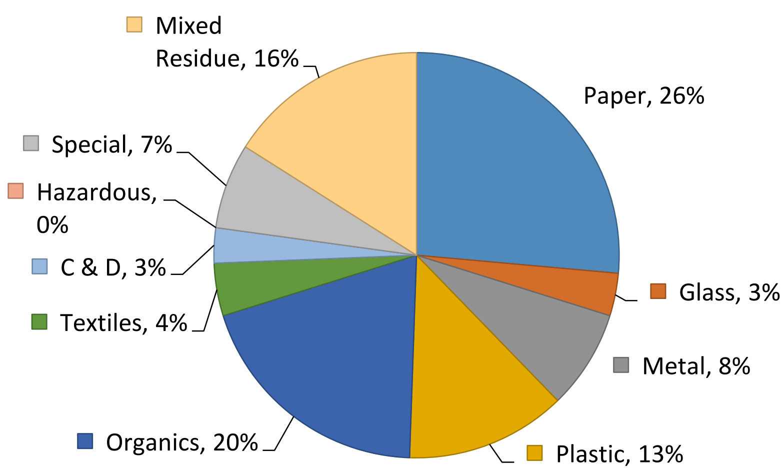

Figure 23. Results from a waste composition study conducted on American Samoa[1]

5.2. Waste reduction

The hierarchy of an ISWM system places waste reduction at the top, followed by recycling, energy recovery, and, last, landfilling last (US EPA 2002). Waste reduction refers to the prevention of materials from becoming waste components at the source of generation. In most cases, this relates to the mass of waste produced, but in some contexts, it also refers to a reduction in the toxicity (or other harmful properties) of a waste material. Increased use of durable goods (e.g., reusable packaging, rechargeable batteries) contributes to waste reduction efforts.

[1] (SCS Engineers 2009)

From a municipal government perspective, waste reduction involves promoting public knowledge, awareness, and willingness to devote time and energy to reducing waste amounts and the associated impacts. Table 4 provides examples of waste reduction often promoted by communities. Public outreach is paramount and highly encouraged in most of the areas visited by our scientists. Waste reduction outreach programs can include, but are not be limited to, print advertising, radio and television commercials, community events, and presentations and activities at local schools.

5.3. Waste collection

A routine and reliable system of waste collection is essential for encouraging proper disposal techniques and for delivering waste materials to their appropriate destinations. In the major cities, waste collection typically occurs with multiple vehicles (often with automated collection) to collect distinct waste streams that have been separated by the local residents (e.g., recyclables, organic, garbage). In remote areas, economically challenged areas, options for collection might be more limited. Mohee et al. (2015) reported that issues with waste collection often directly result in illegal dumping (either on land or in the sea) or open burning of generated wastes.

Table 4. Waste Reduction Methods at government and community level (UNEP 2005, USEPA 2012)

Waste-Reduction Methods	
Government Level	Set regulations and rules.
	Educate and promote community awareness.
	Establish donate and exchange program.
	Work with manufacturers and consumers to design and implement a packaging return program.
	Understand product life-cycle and restrict importing products with high waste residues.
	Limit commercial media such as hard copy flyers and cards.
Community Level	Use reusable bags and containers for shopping, traveling, packing.
	Choose products that are durable, reusable, refillable, and repairable.
	Compost food scraps and yard waste.
	Purchase items in concentrated forms such as dish soap and laundry detergents.
	Buy used products.
	Buy bulk items, reducing packaging from consumption of individual items.
	Lessen the use of material that cannot be recycled; that have less recycling value; that can be hazardous at end of their life cycles (e.g., antifreeze, engine oil, grease).

Other challenges related to the collection observed in the visited small, remote islands on CNMI and American Samoa are difficulties with obtaining and maintaining reliable collection vehicles, as well as the road infrastructure that may sometimes be inaccessible for these collection vehicles, (Mohee et al. 2015). In some communities, collection from each home or business may be an option, but in other cases, the waste generator, or an individual hired by the waste generator, may be required to transport the waste to a centralized container or disposal site.

Collection vehicles can be as simple as open-bed trucks as observed at one remote, economically challenged location (Figure 25). This type of collection program may be staffed by a driver and at one or two waste collectors. Given the need to manually lift and place the trash in the back of the vehicle, residents would generally be encouraged to put the garbage in bags (instead of larger heavier containers). Participation in the collection program is greatly enhanced when a routine collection schedule is maintained. The use of a tilt-frame truck further makes unloading the waste easier at the final destination. In some locations, bags that are heavy with recyclables are placed in a designated part of the truck bed so they can be more easily separated at the tipping location; using different colored or labeled bags for recyclables can also promote recycling. While the implementation of a routine collection may cost communities in terms of transportation vehicles purchase and maintenance, it will generate much needed green jobs for the community and will have a positive impact on the environmental quality of these communities.

In locations where residents or businesses (or hired haulers) are required to take the waste directly to a local disposal facility, public education and outreach are needed so that the location of the designated facility and instruction for disposal are well-understood by the waste generators. At the facility, proper road maintenance and signage directing vehicles to the appropriate disposal site are critical to keeping waste from being improperly disposed of along the route to the facility (Figure 26). An essential component in preventing illegal dumping in areas other than the designated disposal site is cleaning up existing areas with excessive litter and improperly disposed of waste, which may promote propagation of illegal dumping; this may need to be a routine maintenance activity as part of an ISWM, especially in areas where new systems have been introduced. Our researchers observed such cleanup practices at the CNMI’s Marpi Landfill which further promotes proper disposal of wastes by allowing self-haul residents to dispose of waste at no charge, avoiding standard tip fees for loads up to 500-lbs in weight (weight limit waived in times of high waste disposal demand, e.g., a natural disaster) (Leavitt 2005; Saipan Tribune 2015).

Figure 24. An open-bed truck for collecting household garbage

Figure 25. Signage indicating appropriate disposal areas at a municipal waste disposal site

A final component of the collection system, and the ISWM plan as a whole, is the system for collecting fees to pay for the waste-management system. In many cases, this is one of the most problematic features of introducing a new regime. Most local governments find that the fairest and easiest approach is to charge the residents based on their use of the waste-collection service and, in many cases, this service is mandatory. However, care must be taken with implementing any new fee structure so that residents do not resort to illegal dumping. Standard payment mechanisms include a monthly fee as part of a utility bill, an assessment as part of property taxes, or the mandatory purchase of particular bags for waste collection.

6. Resource Recovery

Modern ISWM systems target the recovery of beneficial products from the waste prior to disposal. Such recovery takes place through recycling and recovery of specific waste components (e.g., aluminum cans, cardboard), biological treatment of organic elements of the waste stream and the production of compost and other commodities, and the recovery of energy from waste through thermal treatment processes (e.g., incineration). Recovery of materials and energy from waste is a dominant practice in larger municipalities, but in smaller communities, similar levels of recovery can be hard to justify economically. Maximizing resource recovery limits the overall volume of disposed material, reducing risks associated with landfilling. Segregation of the incoming waste stream provides the maximum opportunity to reduce disposed quantities. This section discusses issues with each of these different recovery options, with a particular focus on remote, economically challenged communities. It is also important that communities continue to comply with all applicable laws and regulations to ensure the protection of human health and the environment. Furthermore, it should be recognized that some management solutions discussed here may not be appropriate for all communities.

6.1. Recycling

In larger communities, residential recycling is accomplished either through a curbside collection program (where recyclables are separated from the garbage and collected separately) or by providing centralized facilities where recyclables can be dropped off. Recycling in remote, economically challenged areas is challenging for several reasons. A key factor in determining the economic viability of a recycling program is the proximity of the recovered materials to respective end markets. Materials recovered in remote, economically challenged areas often require shipping over vast distances to reach an end user, and the transportation costs often outweigh the value of the recovered commodities. Smaller population sizes, and thus less recovered material to offset necessary infrastructure costs, further add to the economic challenges. In more developed areas, recycling programs are often heavily subsidized by government tax dollars, a practice not commonly encountered in small island developing states (Mohee et al. 2015).

Remote, economically challenged communities need to be selective with respect to the materials in the waste stream targeted for recycling. Metal products tend to be the most widely recycled. Ferrous metal (e.g., iron, steel) has a sufficiently established market and is generated in large enough quantities that collection, storage, and off-island shipment for recycling have been economically viable. While the widespread recycling of aluminum was not observed at all communities evaluated, aluminum products, particularly beverage containers, have sufficient value to warrant stockpiling for eventual shipment to a recycler. For comparison, the high cost of aluminum makes it economically feasible even for isolated communities in Alaska to transport by air to recycling centers in more populated areas (Alaska DEC 2011). Other standard components of MSW (e.g., paper, cardboard, plastic) may have established markets, but a larger volume of these materials are needed for the recycling to be economical. Additionally, effort should be made to remove potentially hazardous materials from the recycled waste stream. While able to be landfilled, in designated subtitle D landfills, alternatives to disposal are preferred (e.g., reuse, processing to remove hazardous constituents) if they originate from household sources. Bulky white goods (refrigerators, freezers, etc.) can also be segregated so the Freon or other refrigerants may be appropriately recovered, and the appliances may be crushed to reduce the size and shipped for recycling.

Isolated municipalities can implement several mechanisms to promote recycling once a town has decided to target a given material. Providing a location for stockpiling and processing commodities allows time for the accumulation of sufficient materials for shipment to market, an ample amount of which will generally be necessary, given the disperse populations on many remote, economically challenged islands. Sufficient storage capacity is also beneficial as market values for recovered materials vary with time and external economic conditions, so the ability to retain materials until market prices are high enough is desired as observed in Saipan (Figure 27). That particular facility contained sufficient storage space to allow both waste processing (e.g., baling) and storage of recovered materials; materials are shipped off the island to market when a sufficient quantity are present, and the conditions are suitable.

Figure 26. Waste recycling facility equipped with storage capacity for recovered materials

In the absence of formalized recycling infrastructure, informal recycling was observed at some disposal site through manual sorting (e.g., for reusable or recyclable automotive and equipment parts). Some landfill operators instituted a more formalized process of on-site recycling in which employees sort through loads of incoming waste to recover specific waste components (Figure 12). It is noted that this practice should include appropriate health and safety protocols for contact with waste and work around heavy machinery.

The success of a recycling program relies heavily on the level of community participation, further highlighting the need to implement an outreach program (discuss earlier) and the need for educational tools necessary to inform residents of new policies or how they can change their behavior in support of the program. Some recycling programs are more expensive than others, but there are lower-cost options available to improve recycling in a community and reduce the number of recyclable materials landfilled. Some state and local governments have developed zero waste goals and implemented policies and practices to engage stakeholders to reach this aim.

Zero Waste program planning has been performed by some remote, economically challenged communities with some success. These programs may provide some community education, rally support among stakeholders, and provide a framework for the implementation of new policies. On CNMI, high recycling rates (36% in 2004 for waste incoming to the Marpi Landfill) were observed and attributed to diversion efforts aimed at a variety of waste types, including green waste, concrete, cardboard, white goods, tires, paper, and plastic; diversion efforts are promoted by CNMI's Organization of Conservation Outreach (COCO) (Leavitt 2005). COCO outreach efforts include integration of environmental curriculum in schools, open dump cash for trash cleanup events, and distribution of literature at solid waste management facilities (Leavitt 2005).

6.2. Organics Recovery

The biodegradable organic material, including food waste, yard trash, and paper products, is one of the largest components of the MSW stream (SPREP 2010a). Many larger communities with a goal of materials recovery and landfill diversion target organic components (those without established recycling markets) for treatment through composting or anaerobic digestion. Unlike the recycling markets described in the previous section, successful implementation of organics recycling is not dependent on an end-user market located far from the remote, economically challenged community (Hoornweg et al. 1999, UNEP 2013). Given the issues with waste collection and transport in rural areas, where roads may be inaccessible or narrow, the ability to practice composting or anaerobic digestion at the point of waste generation increases attractiveness for communities in the US Pacific island territories. Rural US Pacific island territory households tend to produce a waste stream which has a relatively high fraction of organic material in comparison to homes on the US mainland, approximately 50% versus 35% on the US mainland making organics recovery a critical component of sustainable materials management strategy (US EPA 2015a, SPREP 2014). The reason for this differential waste composition are the consumption trends in these areas, where there is less consumption of pre-packaged foods and ready-made items. Composting of organics also improves leachate quality at landfills by reducing the organic fraction of the disposed waste (Richards and Haynes 2014). Thus, organics recycling is one of the more feasible as well as important (for the purposes of environmental protection and maximizing landfill space) alternatives for waste diversion in isolated communities where transport issues abound (Mohee et al. 2015). The potential for composting and anaerobic digestion is described in the following sections.

6.2.1. Composting

Composting is the process of aerobically decomposing organic materials such as food waste, yard trash, and paper. This is essentially the same process that occurs in nature, where bacteria and other organisms break down organic wastes in the presence of oxygen into a nutrient rich product. Numerous benefits have been attributed to the practice of composting organic wastes. In addition to diverting materials from a landfill where they would contribute to methane formation, the resulting compost product is high in carbon and nutrients and thus serves as a valuable soil amendment. Soil quality on the islands would benefit from composting practices because it allows the return of nutrients to the ground. Composting is also a technology that is relatively simple to implement on multiple scales, including at the household and community levels and has been explored in pilot programs on other Pacific island communities through the Japanese Technical Cooperation Project for Promotion of Regional Initiative on Solid Waste Management in Pacific Island Countries (J-PRISM) project (US EPA 2009, Richards and Haynes 2014). Both organics only (yard waste) and mixed-waste MSW composting were observed in small island communities, undertaken by private (e.g., hotels composting garden wastes generated on site) as well as public entities (Mohee et al. 2015).

The solid waste industry has considerable experience in composting mixed MSW, but quality limitations of the final product (presence of contaminants) have prompted a transition to organics-only composting as the predominant composting approach. The key to successfully implementing such an approach is, of course, the ability to collect a segregated feedstock. Composting of food scraps at the household level is a relatively straightforward process, if sufficient land area is available and if an adequate supply of vegetative material and soil exist to mix with the waste. At the community level, a more complex suite of issues must be considered, including collecting a segregated feedstock, promoting an appropriate environment for aerobic waste decomposition, and processing the final product prior to use (NSWMSC 2009). Some organic waste collection was reported at some community's marketplace. Alternatively, the municipality may encourage the separation of organic waste at the source (the household or the business), but in communities that have very simple collection systems, this might prove to be a challenge. One approach that has found success in some communities is the designation of separate community containers for disposing of organic waste separate from other waste stream components. It was observed that CNMI, Saipan's Lower Base Refuse Transfer Station, incorporates an area devoted to sorting, grinding, and storing green waste, processing necessary to improve composting conditions (with sufficient exposure to oxygen, this smaller particle size increases the rate of decomposition), thus increasing the amount of green waste diverted (Leavitt, 2005).

The ideal compost recipe includes both brown and green organic materials. Brown materials provide carbon and can include paper (e.g., shredded paper, cardboard) and dry yard waste (e.g., leaves, small branches, straw, sawdust). The green material provides nitrogen and includes wet yard waste (e.g., grass, green leaves) and food scraps (e.g., vegetable and fruit peels, coffee grounds). Brown and green materials are typically mixed at a ratio of approximately three to one (brown to green), by volume. Although all biodegradable organic materials can be composted, vegetable and yard wastes typically work best. Meat and dairy food scraps have the potential to increase odor and pest problems, but as long as they are mixed with sufficient plant-based material, the composting process can accommodate them. Shredding of green materials for size reduction and corresponding increased surface area is a recommended practice to enhance the rate of material decomposition; the increased surface area provides a greater number of surface sites for oxygen to react, accelerating aerobic decomposition (Ragazzi et al. 2014). In addition to food scraps and vegetation, incorporation of sewage sludge at a rate of 0.25-0.5 sludge fraction (in relation to high carbon organics, e.g., yard waste) could further increase compost quality, though typically some dewatering processing is necessary to reduce the moisture content of sewage sludge (contributing significant nitrogen and moisture), without dewatering, the maximum recommended sewage sludge fraction decreases to 0.1 (Ragazzi et al. 2014).

As composting is an aerobic process, the compost piles or windrows must be maintained in a manner that promotes the presence of oxygen within the compost. Several approaches are employed to ensure an aerobic environment. While the use of small piles may allow sufficient air intrusion, it limits insulation and thus piles may not reach a temperature conducive to rapid waste decomposition. Larger piles retain heat better, but they need to be regularly turned (with hand tools or with mechanical equipment). The longer the composting process is allowed to continue, generally the higher quality the end product; a 90-day maturation time was recommended for sewage sludge co-composted with high carbon MSW materials (yard wastes) (Ragazzi et al. 2014). In some cases, pipes or vents are added to promote air migration into the piles. Moisture represents another factor of importance with respect to maintaining aerobic conditions. The compost pile must be sufficiently wet to keep the necessary environment for the microorganisms, but if the pile becomes too wet, anaerobic conditions may develop and result in greater odors.

The resulting compost product can be used for a variety of agricultural and landscaping benefits, including improved soil structure for plant root growth, enhanced water-holding capacity, and nutrient and organic matter addition (USCC 2001). Prior to reuse, the compost may first need to be screened to remove oversized pieces of woody material as well as different items. Screens can be purchased specifically for this type of application, but they can also be fabricated relatively easily from local supplies (Figure 29).

Figure 27. Equipment built for screening compost

6.2.2. Anaerobic Digestion

In contrast to the composting process, anaerobic digestion functions in the absence of air; a different group of microorganisms is responsible for the decomposition of the organic matter. Historically, the primary feedstocks used for anaerobic digestion have included animal waste or sludge from wastewater treatment operations, but more commonly today segregated organics from MSW are being treated anaerobically. During anaerobic digestion, microbes digest the organic materials under conditions similar to those encountered in a landfill and produce a biogas consisting primarily of carbon dioxide and methane. Additionally, a solid product similar to compost can be retrieved, as can a liquid digestate that can be utilized as a fertilizer. Conditions for successful anaerobic digestion are harder to achieve relative to aerobic composting, but the added benefit of fuel product (biogas) production makes this practice desirable for some communities. Use of the gas produced by the digester decreases emission of greenhouse gasses from the overall waste management scheme; gasses generated by waste decomposition are not released to the environment. Additionally, energy needs, which would otherwise be filled by some other greenhouse gas producing activity are offset.

Implementing anaerobic digestion in large communities requires rather extensive capital infrastructure and dedicated operating personnel. These types of systems may not be appropriate for remote, economically challenged communities. However, anaerobic digestion has been applied at a small scale in developing countries (Vögeli et al. 2014, Müller 2007). A significant potential benefit to anaerobic digestion in these cases is the production of biogas, which can be used as a fuel substitute (e.g., for a gas cooking stove). This decentralized power generation is helpful in remotely located communities, where reliable power supply may not be available. Additionally, the use of biogas reduces the need for combustion of firewood, which produces smoke harmful to air quality.

To create anaerobic conditions for the formation of biogas, enclosed-vessel fixed-dome digesters, floating-drum digesters, and tubular digesters are available to designer as options (Vögeli et al. 2014). Fixed-dome digesters are typically constructed underground and composed of two chambers. Organic material is added to a primary chamber where the resulting biogas is collected in the chamber's dome; a second chamber operates as an outlet and overflow tank. Floating-drum digesters consist of a cylindrical reservoir (buried or above ground) equipped with a floating drum over the top of the tank that rises and falls as a function of the biogas pressure developed under the drum. Figure 29 shows an above-ground floating-drum digester used to produce biogas for a cooking stove and a tubular or flexible-membrane digester which utilize plastic or rubber bags (or balloons) as the primary digestion vessel as well as a storage system for the biogas.

Figure 28. Floating drum (left) and Tubular (right) anaerobic digester

An anaerobic digester requires a microbial seed; a mix of water and cow manure is commonly added in increments to build up the microbial population over time. Anaerobic digestion can work under most climatic conditions; however, at lower temperatures the process becomes less efficient and a heating and/or insulation system may need to be installed. A consistent temperature regime is best. The optimal pH range for an anaerobic digester is 6.5 to 7.5. Because of the nature of the microbial process responsible for the anaerobic degradation, the system may become acidic, and the addition of lime, sodium bicarbonate, or sodium hydroxide may be necessary to increase the pH. The appearance and odor of the slurry should be checked regularly. Well-digested effluent should not have an acidic smell, and the pH can be monitored by using litmus paper or a pH meter. If the pH is below 5.5, feeding should be stopped until the pH has stabilized.

The organic material should be fed to the digester on a regular basis, and some amount of size reduction may be required if the waste pieces are too large. Larger size operations may require dedicated personnel to collect waste for digester feedstock, operate size reduction equipment, and ensure gas producing conditions are stable. The hydraulic retention time (the amount of time that the liquid portion remains in the reactor) varies depending on the type of reactor, system temperature, and waste composition, and can range from just several days up to 40. Each ton of feedstock produces approximately 80 to 200 cubic meters of biogas; each cubic meter of biogas is estimated to have the capacity to power a gas stove for two hours (Vöegeli and ZurbrÜgg 2008). If biogas is used as cooking fuel, stoves should be cleaned regularly to avoid clogging and moving parts greased and checked to ensure they are gas tight. Leaks need to be immediately repaired. Condensed water in the pipes should regularly be drained to provide adequate gas flow. Gas pipes above ground, valves, fittings, appliances, and gas storage containers should be checked regularly for leaks.

6.3. Energy from Thermal Waste Treatment

Many larger communities rely on incineration as an effective MSW management option. In this process, combustible components in the waste (primarily paper, wood, and plastic products) are converted into ash, flue gas, and heat, under excess air conditions. The heat generated from the incineration process can be used to produce electricity, and thus this technology is commonly referred to as waste to energy (WTE) in the US. The WTE process reduces the volume of waste requiring landfill disposal. While WTE is a proven technology and is relatively common in Europe, Asia, and some parts of the US, these facilities require a significant capital investment and a highly trained operational staff. As such, WTE plants are typically only feasible in locations where the amount of waste combusted is several hundred tons or more per day. In the US, the smallest plant is rated at a capacity of 175 tons per day (Berenyi 2012). Thus the application of WTE technology or other emerging thermal waste processes (e.g., gasification) for remote, economically challenged communities is likely not feasible. Furthermore, some communities, may prohibit WTE and waste incineration by statute, so local regulatory rules should be consulted as part of an investigation of this technologies feasibility.

Opportunities do exist for the use of thermal waste treatment as a disposal method in remote, economically challenged communities (without the recovery of energy). The reasons such technologies are not advisable, since they don’t include energy recovery, are described in the next section for completeness of the report.

7. Waste Disposal

The least preferable options as part of an ISWM system hierarchy are disposal through combustion (with no energy recovery) and landfilling. In the US as a whole, the burning of MSW without energy recovery is rare. Despite the growth of the recycling industry and the ongoing operation of a number of WTE facilities, landfilling remains the predominant management technique for US MSW (ash remaining after waste combustion¬, comprising about 15 to 25% by mass of the initial waste, is typically landfilled). As stated at the beginning of this document, most communities in the US dispose of their MSW in Subtitle D (or equivalent) landfills.

It is noted that some combustion information presented here comes from guidance provided to locations that may currently meet the Subtitle D small-community exemption (e.g., remote, economically challenged Alaskan communities, Native American communities in the arid Western US) Nothing in this section should be viewed as a regulatory determination on whether these technologies are permissible under current US regulations. Local regulations should always be consulted to ensure waste management practices do not violate any existing specific rules.

7.1. Combustion

Waste combustion reduces the overall volume and mass of material which will ultimately require disposal. Combustion of wastes must be practiced in compliance with 40 CFR 257, which prohibits the open burning of solid waste; 40 CFR 257 defines open burning to mean combustion without 1) control of combustion air to maintain adequate temperature for efficient combustion, 2) containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and 3) control of the emissions of the combustion process. In the open burning process, waste is allowed to burn with little control of the combustion process, and there is a high potential for uncontrolled fires. During open burning, temperatures may not be high enough to destroy entirely the combustible materials. Thus, higher temperatures are preferred (generally above 1,200 °F). Incomplete combustion at low temperatures produces an ash which is attractive to scavenging animals and has the potential to produce a higher strength leachate at landfills when disposed of (Emswiler and Crimp 2004). The prohibition on open burning does not apply to facilities combusting agricultural wastes.

It is noteworthy at this point to mention that the presentation of the various thermal technologies are included here for completeness of the report and is not intended to support such technologies. Communities should always evaluate and adhere to all regulatory requirements before implementing a solid waste management system. However, in general, incinerators are engineered to control the combustion process better by creating a high-temperature environment that leads to more efficient waste destruction and less air pollution, in contrast to the open burning process. Several types of incinerators - burn boxes, air-curtain incinerators, and multiple-chamber/batch starved-air systems - may be appropriate only for the occasional burning of agricultural wastes in the field, silviculture wastes for forest management purposes, land-clearing debris, diseased trees, debris from emergency clean-up operations, and ordnance. It is noted that these technologies are not allowed for municipal waste management. These incinerator types are summarized in Table 5 and described in greater detail below.

Table 5. Summary of incinerators used for agricultural waste management

Incinerator	Description
Burn Box	Burning process occurs in a single enclosed chamber equipped with a smoke stack. Air is usually supplied passively to the burning chamber; however, a powered blower could be added to enhance air flow. Waste is placed on grates inside the upper portion of the chamber to allow air access to the reaction from all sides. Ash is accumulated in the lower portion of the chamber during and after burning.
Air-Curtain Incinerator	An air-curtain incinerator is equipped with a blower forcing a thin curtain of air at high velocity across an open, burning chamber. The air-curtain stalls and slows down the smoke particles on their way out of the chamber. In doing so, a higher temperature is maintained inside of the chamber and smoke particles are re-burned to reduce emissions.
Multiple-Chamber, Batch Starved-Air System	This dual-chamber, batch-feed, starved-air incinerators are usually referenced as Thermal Oxidation System (TOS), or Batch Oxidation System (BOS). Waste is loaded using conventional equipment into a primary gasification chamber, where waste is burned under a controlled low oxygen conditions and is converted to a synthetic gas. The synthetic gas enters into a secondary oxidation chamber where the temperature is increased to a higher level (e.g., 1200 °C), where toxic air pollutants are destructed. This type of incinerator is the most efficient at reducing air pollution from incineration.

7.2. Landfilling

Land disposal remains a dominant method of waste disposal worldwide (Hoornweg and Bhada-Tata 2012). However, given the limited space available on the islands, land disposal is not a preferred waste management option. In the remainder of this section, the requirements for a Subtitle D Part 258 MSW landfill (generally just referred to as 'Subtitle D') and Part 257 non-MSW landfill are first described, followed by a detailed discussion of specific operational aspects of landfilling. Additional guidance for operating land disposal sites in remote, economically challenged communities such as the Pacific territories can be found in several other documents (Rushbrook and Pugh, 1999; SPREP, 2010b; Munawar and Fellner 2013). In addition to federal criteria, local regulatory criteria may also apply; and thus, it is important to consult local regulatory agencies for specific rules.

7.2.1. Summary of the Subtitle D Landfill Requirements

The solid waste regulations part of RCRA ban the open dumping of all solid waste; regulations require landfills for household waste (i.e., MSW landfills) comply with detailed minimum protective measures, such as use of liners and leachate collection systems. Landfilling of other types of wastes (e.g., C&D debris) are also governed by US regulations, which require certain basic environmental protection measures (e.g., location restrictions, control of disease vectors), including groundwater monitoring if hazardous wastes are accepted as part of the waste stream. For the complete requirements, please see 40 CFR 258, and/or applicable state regulations.

Subtitle D Part 258 regulations (40 CFR 258) relevant to MSW landfills in the US Pacific island territories include location restrictions, operating criteria, design criteria, groundwater monitoring and corrective actions, closure and post-closure care, and financial assurance criteria for MSW landfills. Table 5-2 summarizes the key requirements of the regulations. Some of the practices outlined in the Subtitle D rules are fundamental elements of sanitary landfill practice (e.g., covering the waste), but key features that distinguish a Subtitle D landfill from a sanitary landfill are the requirements of an engineered liner system and a leachate collection and removal system (LCRS). The criteria of Subtitle D Part 258 are the minimum national US standards determined to provide protection of public health and the environment. In one community, due to concerns of the local regulatory agency and local residents, a landfill was constructed with an engineered liner that includes redundant protection from potential release of leachate.

A Subtitle D landfill liner consists of 2 feet of compacted soil with a maximum hydraulic conductivity of 10-7 cm/sec overlain by a geomembrane liner (typically a 60-mil HDPE geomembrane). The liner creates a barrier to intercept leachate produced in the landfill. The LCRS consists of a network of drains placed over the sloped bottom liner so that the depth of leachate resting on top of the liner does not exceed 30 cm. Leachate is removed from the landfill by placing pumps at low spots in the LCRS, and the pumped leachate is then treated before being discharged to the environment. Groundwater surrounding the landfill unit must be monitored, and off-site migration of gas must be controlled. Suspension of groundwater monitoring requirements via approval of a submitted non-migration petition showing negligible potential for migration of hazardous constituent, though not inapplicable to landfills on US Pacific island territories per se, generally have been only successfully implemented at sites experiencing lower rainfall rates (<25 inches per year) than the US Pacific island territories. The Subtitle D regulations contain provisions for closing the landfill with an engineered cap as well as maintaining and monitoring the landfill for at least 30 years following closure.

Other types of landfills that are allowed under current federal regulations are described in 40 CFR 257. While location restrictions and groundwater monitoring requirements are similar for both Part 257 and Part 258 sites, these landfills can only accept industrial, construction and demolition type wastes and septic tank waste (municipal waste is not allowed at these locations). Furthermore, these types of landfills do not require a liner system, and the daily cover is needed, but the thickness and type are not prescribed. Overall, in the continental US, the cost of constructing and maintaining a Part 257 site are lower than those for a Part 258 MSW site. Thus, the implementation of a successful waste segregation regime where waste that can be disposed of in a Part 257 landfill may provide a significant reduction in cost and an increase in MSW-landfill capacity for communities.

7.2.2. Site location

Solid waste disposal facilities should be located to minimize potential impacts on human health and the environment. Disposal sites should be located away from residential areas and sources of drinking water. The flow direction of underlying groundwater should be considered, as should any nearby surface water that could be affected by waste-disposal operations. Sensitive ecosystems, both terrestrial and aquatic, should be evaluated with respect to potential adverse effects posed by landfilling.

Other considerations for locating a disposal site include the availability of cover soil, proximity to other community activities where heavy equipment may be available, and conditions of the site with respect to leachate drainage and treatment. As described in the following section, application of cover soil to waste offers numerous advantages and a nearby source of soil is necessary. Waste compaction is also important; if a community does not have the resources to purchase dedicated waste compaction equipment, shared use of material from other community activities (road construction, soil moving) may be a viable alternative. A disposal site that has a natural land slope provides the opportunity for gravity leachate drainage without the use of mechanical pumping equipment.

7.2.3. Fundamental Sanitary Landfill Practices

General basic sanitary landfilling practices (not specifically described in 40 CFR 258, with which US Pacific island landfills must comply) are applicable to all disposal sites. Waste compaction is an essential tenet of sanitary landfilling, and allows more waste to be placed in a given landfill area (thus minimizing overall land area requirements), helps prevent air intrusion into the trash pile (a potential source of fires), and decreases the rate of water infiltration into the waste. Equipment specifically designed for waste compaction is typically utilized at larger sites (Figure 30), but other types of earth-moving equipment (e.g., bulldozers) can also be used to achieve a degree of compaction.

Figure 29. Compactor on working face of landfill at Marpi Landfill in Saipan, CNMI

One of the most important features of a sanitary landfill is the daily placement of soil or alternative (e.g. ash, compost) cover on top of the waste, after the waste has been dumped (6 inches daily is required by Part 258, unless a variance is granted). Covering the waste with soil significantly decreases opportunities for fires at the landfill surface, reduces nuisance odors, minimizes attraction of disease vectors to the waste, and keeps garbage from being blown off site by the wind. A good layer of cover soil, especially in combination with an adequately sloped landfill surface, helps shed rainwater from the site, thus minimizing leachate generation. The soil retains some of the moisture that does not run off and allows for evaporation, and the biological and chemical reactions in the soil help mitigate the release of odorous and harmful chemicals contained in landfill gas. Size-reduced woody debris (e.g., yard trash) has been used as a cover soil amendment and has been found to assist further in removing chemicals in landfill gas.

Table 6. Summary of RCRA Subtitle D (40 CFR Part 258) Landfill Requirements (consult 40CFR-258 for complete regulations)	
40 CRF Part 258 landfill requirements	
Location restrictions	• New landfills or expansions of existing landfills may not be constructed in the following areas without approval from EPA or the director of an EPA-approved state solid waste permit program: within 5,000 to 10,000 feet of an airport (depending on the type of aircraft used at the airport) due to bird hazards to aircraft, a floodplain, a wetland, fault areas, a seismic impact zone, or in an unstable area. • To gain approval, appropriate demonstrations must be made proving that the MSW landfill site will not have detrimental effects on human health and the environment (as is specified in Part 258).
Operating criteria	• MSW landfill facilities should exclude the acceptance of hazardous waste by implementing random inspections, records of inspection, training personnel to recognize hazardous waste, and notifying the state director for authorized States under Subtitle C of RCRA (or the EPA Regional Administrator if in an unauthorized State) of discovered unauthorized hazardous waste. • Six inches of earthen cover material should be placed over solid waste at the end of each operating day or at more frequent intervals, if needed (alternative materials and thickness may be approved). • A facility should prevent or control on-site disease vectors. • MSW landfill facility is to monitor the potential for explosive gas by not allowing methane gas generated to exceed 25% of the lower explosive limit for methane in facility structures or at the property boundary, and the facility must implement a routine methane monitoring program • The facility is not to violate the Clean Air Act, and open burning of solid waste is prohibited (except in the specified circumstances). • Public access to the facility must be controlled. • Landfill owners are to design, construct, and maintain a run-on control system to prevent flow onto the active portion of the landfill and a run-off control system to collect and control runoff from the landfill. • MSWLFs cannot discharge pollutants to surface water, including wetlands (with the exception of engineered permitted wetlands designed to contain and treat leachate). • Bulk or non-containerized liquids cannot be accepted at MSW facilities unless specified restrictions are met. • An MSW facility must maintain adequate recordkeeping as specified by 258.29.
Design criteria	• An MSW facility must be constructed so that concentrations of specified constituents will not be exceeded in the uppermost aquifer at relevant points of compliance. • The MSW landfill is to be built with a composite liner consisting of the upper component a minimum 30-mil flexible membrane liner (FML) and a lower component of two feet of compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec. FML layers of HDPE should be at least 60-mil thick. • Liner construction must include a leachate collection system that is designed and constructed to maintain less than a 30-cm depth of leachate over the liner.
Groundwater monitoring	• Groundwater monitoring for MSW landfills is to be conducted throughout the active life of the landfill and during landfill closure and post-closure care • A sufficient groundwater control system is to be installed such that monitoring wells are of appropriate location and depth, and ensure monitoring results that provide an accurate representation of ground-water quality at the background and downgradient wells installed in compliance with §258.51(a). The groundwater monitoring program must include consistent sampling and analysis to ensure the accuracy of results.

Table 6. Summary of RCRA Subtitle D (40 CFR Part 258) Landfill Requirements (consult 40CFR-258 for complete regulations)	
	• Detection monitoring is required at monitoring wells for the provided list of specified inorganic (copper, nickel) and organic (e.g., acetone, benzene) constituents (at a minimum). • When a statistically significant increase over background levels is detected for one or more constituents, assessment monitoring is required which involves additional sampling and monitoring. When constituents are detected at levels significantly exceeding groundwater production standards, an assessment of corrective measures must be completed and based on the findings of the assessment; a remedy is then selected to remediate the situation with corrective actions. • Groundwater monitoring requirements may be suspended by the director of an approved State RCRA Subtitle D program if it can be demonstrated that there is no potential for migration of hazardous constituents from the MSW landfill unit to the uppermost aquifer during the active life of the landfill and post-closure care period. The demonstration must be certified by a qualified groundwater scientist and approved by the Director of an authorized state, based on site-specific field collected measurements and contaminant fate and transport predictions.
Corrective Action	• Assessment of corrective action to remedy exceedances of groundwater protection standards must be initiated within 90 days of such exceedance and completed within a reasonable period of time. • Corrective action may not be required if contamination is from multiple sources and cleanup of MSWLF release site would provide no significant reduction in risk, contaminated water is not a current or potential source of drinking water and not hydrologically connected with waters to which hazardous constituents are migrating or are likely to migrate in a concentration that would exceed the groundwater protection standard, or remediation is not technically feasible/would result in unacceptable cross-media impacts. • Remedy selected must be assessed for long and short term effectiveness potential. • After the solution is selected, it must be implemented by the landfill owner/operator, a schedule must be selected for completion of all remediation activities, and a groundwater monitoring program must be established to indicate efficacy of selected remedy (as well as comply with minimum requirements of assessment monitoring program). • Corrective action must continue until all required steps have been completed and the site is in compliance with groundwater protection standards for three consecutive years, or an alternative period of time specified by the director of the state enforcement agency. • Site owner/operator must obtain certification that the remedy is completed and notify the director of the state enforcement agency.
Closure and post-closure care	• A final cover system meeting the specified criteria must be installed when the landfill is closed. • Post-closure care is to be conducted for 30 years after closure of the landfill. This includes maintaining the LCRS, groundwater monitoring, and maintaining and operating the landfill gas monitoring system.
Financial Assurance	• The regulations requires demonstration of responsibility for the costs of closure, post-closure care, and known corrective action. • Adequate funds must be available to ensure that if the primary responsible parties cannot meet their obligations (e.g., owner/operator declares bankruptcy or lacks technical expertise required), a third party can be hired to complete required activities. The possibility of a third party completion of closure, post-closure, and corrective action should be assumed when calculating costs and preparing the written site-specific estimates. • Costs are calculated on a conservative basis, assuming the most expensive closure and post-closure conditions and must be annually adjusted to account for inflation. • Financial mechanisms available include trust fund, surety bonds guaranteeing payment or performance, letter of credit, insurance, corporate financial test, local government financial test, corporate guarantee, local government guarantee, state-approved

Table 6. Summary of RCRA Subtitle D (40 CFR Part 258) Landfill Requirements (consult 40CFR-258 for complete regulations)	
	mechanism, or state assumption of financial responsibility.

Another critical element of sanitary landfill practice is the controlled placement of the waste. The area where waste is unloaded (tipped) and compacted should be minimized (a large exposed working face should be avoided). This applies in particular to the areas of US Pacific island territories subject to extreme weather events because of the potential for waste scattering and high leachate generation volumes due to increased ability for liquids to infiltrate into the waste mass where waste is uncovered (Eckelman et al. 2014). The waste should be placed so that cover soil can be applied most efficiently. This may involve placing the waste in an excavated trench that is later covered with soil (from the excavation, i.e., the trench-and-fill technique). In other cases, waste is placed on the ground surface and then covered with soil that is stockpiled nearby. Fencing the landfill area helps keep wildlife and unauthorized people from the waste and can contribute to control blown litter.

7.2.4. Leachate Control

A primary pathway for chemicals to migrate from the landfill to the surrounding environment is through contact with water. As described in Section 2, leachate resulting from the interaction of garbage and water can contaminate groundwater and surface water. Locations with high rainfall volumes, groundwater tables relatively near the surface, and nearby surface water bodies should be especially aware of the potential for off-site contamination through leachate.

A fundamental step in leachate control is preventing leachate generation. Disposal of wet wastes (e.g., septage, wastewater) with other garbage should be avoided. Many of the sanitary landfill practices outlined above minimize leachate formation. When the area of the waste placement is reduced, less leachate will result. Waste compaction and cover soil application will reduce the amount of rainfall that infiltrates into the garbage and forms leachate. The landfilled waste should be graded to drain stormwater away from the waste, surrounding terrain should be graded to minimize the flow of stormwater onto the waste, promote drainage, and control runoff from the landfill. Standing water on, adjacent to, or near the landfilled waste should be avoided.

The Subtitle D Part 258 landfill regulations for sites accepting MSW require a liner and an LCRS; thus, the leachate is removed from the landfill before it migrates into the underlying soil groundwater. Operators of disposal sites without a Subtitle D liner may still have the opportunity or need to drain leachate from the landfill. For example, as discussed later in this section, the Fukuoka-style landfill typically uses a leachate collection system placed above a natural earthen liner without the utilization of a geomembrane. However, in order to comply with federal regulations, the Fukuoka-style landfill would have to be constructed with a Subtitle D Part 258 liner. Furthermore, waste has to be covered to minimize odors and disease transmission.

Subtitle D Part 258 requires that the depth of leachate on the liner be maintained at 30 cm or less; typically pumps are employed to convey leachate from the LCRS and comply with this regulation. Where possible, original site grades should be utilized so that leachate can be drained by gravity to comply with the 30 cm head on the liner requirement while minimizing costs. This is particularly the case for sites in remote, economically challenged locations. This should be part of the original planning of the disposal site as construction of the LCRS must precede waste placement. Large landfill facilities that collect leachate will often transport collected leachate to a wastewater treatment facility or provide some form of treatment on site. For landfills serving remote communities, treatment systems that rely on power, chemicals, and intensive operating involvement may not be feasible. Thus these communities may want to consider other options allowed under Subtitle D.

7.2.5. Gas Control

The potential risks posed by landfill gas were described in Section 2. Landfills address the problems created by landfill gas by constructing and operating a gas collection and control system (GCCS). Most GCCS utilize gas wells placed within the waste (usually vertically, but sometimes horizontally) to provide a controlled exit point for gas to leave the landfill. When waste decomposes, gas pressures build up in the landfill, and the gas migrates to the surrounding environment following the path of least resistance (ideally installed gas wells). At large landfills the wells are connected to a mechanical extraction system and the collected gas is either flared or used for energy production. At smaller sites, similar to those which operate in the US Pacific island territories, the gas wells provide passive venting of the landfill gas to the atmosphere, thus minimizing potential off-site migration of the gas through the surrounding soil.

Installation of a GCCS is mandated by New Source Performance Standards (NSPS) of the Clean Air Act (CAA) rather than Subtitle D RCRA, and only for landfills with a design capacity >2.5 million metric tons with a predicted gaseous release of >50 Mg/year of nonmethane organic carbons (NMOCs). While some smaller remote, economically challenged community's waste sites may not reach this threshold, a degree of gas control may be provided through the use of good cover soil practices. If active gas collection system is not required, communities may want to construct the gas wells as the waste is being filled, using locally available materials as presented in Figure 32. The figure shows a landfill site where gas wells have been constructed with rock kept in place with wire (similar to a rock gabion); a vent pipe is positioned in the center of the well. Waste is placed in the well as part of disposal operations, and when an appropriate waste height is reached, the well is extended upward. Other materials have been used in a similar fashion to construct gas wells, including drums and tires.

Figure 30. Landfill gas well built with rock encased in wire

8. Hazardous and Special Waste

Another waste challenge faced by communities is the management of hazardous and special wastes that should be handled differently than typical garbage. Remote, economically challenged communities face additional challenges with respect to these wastes because appropriate treatment technologies for these materials may not be locally available.

8.1. Medical Waste

Healthcare activities lead to the production of medical waste that, if poorly managed, can result in serious threats to human health and the environment. These wastes include infectious wastes, chemical or pharmaceutical wastes, expired pharmaceuticals, soiled bandages and dressings, contaminated sharps, and radioactive or cytotoxic wastes. Where possible, these residues should be retained at the point of generation (e.g., a medical clinic or hospital) until they can be shipped to any appropriate treatment or disposal location. In cases where large volumes of these materials are produced making long-distance transport difficult, purchase of appropriate treatment equipment may be necessary. This may be the case with infectious medical waste.

Options for medical waste treatment include incineration or sterilization. Infectious waste should be properly segregated from normal garbage at the point of generation to minimize the amount of material requiring additional treatment. The most common method for sterilization is autoclaving, a sterilization process that utilizes high-pressure steam for 15 to 20 minutes. Several vendors sell sterilization systems designed for smaller hospitals and clinics. Figure 33 shows an autoclaving system installed at a hospital on American Samoa. Following autoclave sterilization, the material is size reduced and disposed of in a landfill.

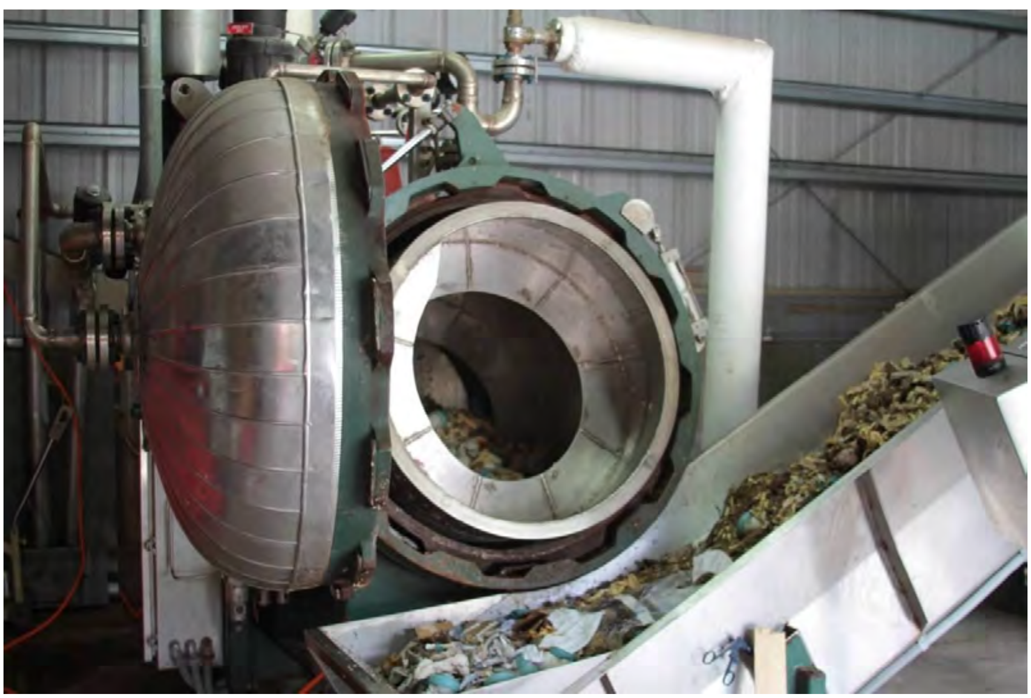

Figure 32. Autoclave at the medical clinic in American Samoa

8.2. Other Hazardous Waste

A number of other potentially hazardous wastes may be encountered as a result of household and commercial activities. Table 8 summarizes a number of these, along with recommended management practices. For many of these materials, collection, storage, and shipment to an appropriate recycler is the best option.

Table 7. Typical community hazardous wastes and recommended management practices

Waste	Description	Recommended management practice
Used oil and filters	Motor oil, transmission fluid, differential oil, brake fluid, power-steering fluid, and transaxle fluid	◦ Used oil that is not mixed with other substances such as gas, antifreeze, or solvents is typically recyclable. ◦ Burning used oil is a common practice and can be integrated with waste to energy system. ◦ Setting up a central collection point is a good way to simplify the collection process. ◦ Any used oil that cannot be burned or otherwise utilized in the community must be shipped out of the community for disposal by a licensed contractor.
Household Hazardous Waste (HHW)	Hazardous materials disposed of by residents from their homes, including cleaners, paints, pesticides, and other chemicals that are hazardous but are not specifically exempted from regulation as hazardous waste	◦ Although HHW could be disposed of with regular trash in compliant Subtitle D MSW landfills, it cannot be disposed in open dumps, and it is recommended that HHW is treated separately at a designated treatment or disposal facility. ◦ Educate residents about HHW categories and the importance of separating them from regular trash. ◦ Organize collection events for HHW on a regular basis. ◦ Store and organize HHW in a clear, labeled space, off the ground and under cover; preferably in a containment area ◦ Work with contractors for a safe and efficient way of disposal.
Antifreeze	Antifreeze contains chemicals that can be toxic to people, plants, and animals.	◦ Antifreeze must be managed and stored to prevent impacts to the environment and public health, similar to how HHW is managed.
Batteries	Button cell batteries Rechargeable batteries Alkaline batteries (including zinc carbon and zinc chloride batteries) Lead-acid batteries	◦ Batteries should be stored in an intact-plastic container or on an impervious surface and under cover to protect them from the weather. ◦ Leaking batteries should be separated from non-leaking ones; acids from the leaking batteries can corrode the other batteries. ◦ Keep the seal loose on the storage containers to avoid the buildup of explosive hydrogen gas. ◦ Batteries should be stored away from sources of sparks or flames.
Asbestos	Asbestos is a group of naturally occurring minerals composed of long, thin fibers and fiber bundles. The minerals have high tensile strength, excellent insulating properties, and are a fire retardant. Inhalation of asbestos fibers may result in serious health issues, including cancer in humans.	◦ Environmentally sound asbestos disposal options are likely to be restricted to either local disposal in a secure landfill, transport to and disposal in a secure offshore landfill, or disposal at sea encased in concrete. ◦ Stabilizing asbestos in occupied buildings prior to its eventual removal should be considered an urgent priority to minimize future exposure of the public to asbestos fibers.
E-waste	E-waste typically refers to end-of-life electrical and electronic products, including computers, printers, photocopy machines, television sets, washing machines, radios, mobile phones and toys, which are made of sophisticated blends of plastics, metals, and other materials.	◦ The electrical and electronic waste contains hazardous but also valuable and scarce materials such as metal and alloys that can be recovered and recycled. ◦ Proper management and disposal of E-waste are essential to the long-term protection of local and regional Pacific environments, as well as to the maintenance of long-term regional sustainability. ◦ Hold regular collection events and accept E-waste. ◦ Collect E-waste until enough has been gathered to make off-island shipping more affordable.

9. Contracting for New Solid Waste Treatment Technologies

Local governments are often approached by outside vendors offering technologies or services for treating or disposing of solid waste. Commonly marketed technologies include thermal treatment systems (incineration, gasification, pyrolysis), often with an energy recovery component; biological treatment technologies (composting, anaerobic digestion); and processing for advanced recycling. These technologies may indeed offer many benefits to local communities with respect to waste management, but because they may have a limited operational track record and since they often necessitate relatively long-term contractual obligations related to waste input and energy/materials revenue, local government officials should conduct a careful evaluation before entering into any agreement.

Unfortunately, there are many examples of communities investing in technologies that promised benefits but for a variety of different reasons, were not successful. Examples of questions and considerations that should be examined as part of the evaluation of any new solid waste management technology include:

- At what scale is this proposed technology currently used? Has this technology been implemented beyond the laboratory or pilot scale, and if so, for how long? Are there any facilities of a similar size (as proposed) in operation elsewhere and can they be visited? The decision makers should consider visiting some of the existing facilities using the proposed technology.
- What are the land and related infrastructure requirements, and who provides these?
- What minimum level of waste input must be guaranteed for this technology to operate correctly or to be economically feasible?
- What are the process residuals (e.g., ash) and their associated chemical and physical characteristics? How will these residuals be managed and who is responsible for managing these?
- How are the revenues associated with the sale of any energy or recovered materials shared? What happens if the markets for energy or recovered materials dramatically change?
- What is the minimum contract duration?
- Who maintains ownership of the property after the facility has closed or otherwise ceased operation?
- If the facility were shut down, who would be responsible for disposing of any remaining waste or dismantling the facility?
- Are contractual safeguards in place to ensure provision for any legal dispute which should arise between the municipality and the public entity?

When waste treatment technologies result in the generation of electricity or other forms of power, care must be taken to negotiate an appropriate power purchase agreement (PPA) in the event the community owns the power generation facility. A PPA is a long-term contract (typically up to 30 years) between an energy company and an entity (municipality, county) that agrees to purchase electricity generated by the project. Worldwide, such agreements are used by solar facilities, biomass plants, wind energy projects, and waste to energy (WTE) plants. The agreement specifies a payment to be made only for power actually delivered within a predetermined output range. The customer is often obligated to take all power delivered. In the US, the private ownership of the renewable energy facility can allow the project to qualify for federal and state tax incentives (US DOE 2011).

For a community with little experience in alternative energy or beneficial use contract procedures, obtaining appropriate guidance from experienced legal, financial, and technical professionals is of critical importance. It is of particular importance to specify options for the renegotiation of the contract and the terms for ending the contract if either the energy producer or buyer defaults on contractual obligations (Marron et al. 1997). US EPA (2015c) highlights the importance of considering taxation issues in terms of which entity legally owns the system, providing an insurance policy, and obtaining demonstrations of good standing and previous success by the proposed operator. Equally important is the set-up of procedures and timeframes for financial statements and payments, the establishment of loans and necessary accounts, site sale and/or lease agreements, and significant land use and environmental permitting.

Local governments that own power generation facilities should evaluate the following questions and considerations when negotiating a PPA with a vendor or utility:

- What are the estimated power generation and predicted changes over the life of a proposed contract?
- How will the implementation of waste reduction measures impact the size of a new system?
- Are prospective vendors required to compete through a request for qualifications (RFQ) or request for proposals (RFP) process?
- Has the proposed system been reviewed by parties with relevant expertise (e.g., legal, environmental, financial, engineering)?
- Has the contractual duration been minimized for greater flexibility in implementing/considering other alternatives?
- Have power wheeling charges been taken into account? The utility may pose power wheeling charges, potentially applicable when power is transferred from one utility's service area to another if the power is sold to a utility that does not own the power grid at and around the site.

10. Summary

The report presented the environmental and human health risks posed by improperly managed solid wastes are described. Fundamentals, such as understanding local waste characteristics, opportunities for waste reduction, and waste collection are reviewed. Recycling can be more challenging in remote, economically challenged locations because transportation costs often outweigh recoverable market value. High community participation rates and sufficient storage capacity for stockpiling materials are essential features of a successful program that recycles large quantities of materials at rates comparable to the US mainland. Source-segregating and biological treatment of organics by composting or anaerobic digestion provide a landfill diversion step not generally limited by transport distances. Both organic treatment methods produce a residual which can be beneficially used, with an added benefit of anaerobic digestion involving the production of gas usable for fuel. Energy recovery from waste through traditional thermal treatment methods will, in most cases, not be feasible because of the small amount of wastes produced and the high capital costs of these technologies.

A number of design and operational approaches are required to reduce environmental impacts from landfills. (Please see 40 CFR 258 for the minimum federal criteria for municipal solid waste landfills.) Site location is critical to avoid sources of drinking water and sensitive environments. Waste compaction, cover soil placement, and proper configuration of the landfill disposal area help minimize issues such as fires, odors, and disease vectors, and can reduce the potential for off-site migration of pollutants from leachate and landfill gas. Landfill gas problems can be reduced through implementation of good cover soil practices and installation of gas vents constructed with locally available materials. Lined MSW landfilling capacity can be preserved by the construction of non-municipal landfills accepting only certain non-hazardous, non-municipal waste materials, operating in compliance with 40 CFR 257, and by sustainable management practices that divert certain materials from the disposal waste stream. For areas seeking to adopt compliant alternative waste management technologies, contract development issues are also discussed.

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