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Waste Disposal in the Tambon of Sang Khom, Thailand

AN INTERACTIVE QUALIFYING PROJECT REPORT

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Abstract

Our project team evaluated the current waste disposal system in the villages of Sang Khom, province of Udon Thani, Thailand, by obtaining a physical description of the system and assessing its potential health and environmental problems. We assessed the feasibility of alternative systems by considering the technical feasibility and social and environmental implications. We considered Sang Khom's available budget to create recommendations for improving their waste disposal system. We also recommended education programs to increase community awareness concerning waste disposal.

Executive Summary

This project, sponsored by Thailand Senator Somkid Sreesangkom, was designed to assess the need for, and possibility of, establishing a new waste disposal system in the tambon[1] of Sang Khom in the province of Udon Thani, Thailand. Sang Khom consists of 12 villages and has a total population of 8,017, of which nearly 90 percent depend on agriculture as an occupation. The local government of the tambon consists of 24 elected council members that set local ordinances and are responsible for the village's infrastructure and the overall well-being of the tambon. Throughout this project, we used feedback from the council members to create a final proposal that was given to our Sponsor, the Tambon Council, and our school, Worcester Polytechnic Institute.

The first objective of this project was to assess the current waste disposal method used in Sang Khom. Through observation and interviews, we determined that the current method negatively impacts the local environment and could potentially harm the tambon's population. Many household collection bins remain uncovered, which allows disease vectors such as dogs, rodents, and chickens to access the waste. However, the actual disposal method, which consists of open dumping and open-air incineration, is of more concern to our team and to those interviewed during this project. To determine whether or not this disposal method is harmful to the local environment, we first assessed the possibility of groundwater and surface water contamination. During the rainy season, leachate can form underneath the disposal site and is not collected or treated. This leachate can seep into the ground and migrate to the underlying water table. Though a test of well water near the disposal site indicated toxic levels of heavy metals found in common landfill leachate, we were unable to conclude whether or not the leachate was responsible for this pollution due to a low seasonal water table level. However, it is possible that local surface water, used for fishing and rice farming, is being contaminated by the leachate.

Another concern with the current disposal site is that the open-air incineration emits toxic dioxins and particulate matter that could potentially be cancer causing. A final concern is the excessive amount of flies that are found in and around the disposal site. Because the waste is rarely covered with soil, flies have easy access to food and live at the site. Villagers in Ban Khok, located 1.5 kilometers south of the disposal site, complained to our team about these flies. In addition to being a nuisance, these flies can act as disease vectors, carrying diseases such as salmonella to humans.

As part of our second objective, we assessed the technical, financial, and social feasibility of improving the current system and possibly establishing an entirely new system. Because of Sang Khom's low budget, we determined that an environmentally sound incinerator would not be feasible for construction.

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[1] A tambon is a group of villages. The tambon of Sang Khom is one of six tambons in the district known as Sang Khom in the Province of Udon Thani.

Also, most incinerators require a waste input nearly 65 times the waste generated in Sang Khom. We also assessed the possibility of supplementing a land filling system with a municipally-run composting system and/or a municipally-run recyclables collection program. Both of these options were found to be infeasible presently due to cost considerations. Also, the market for recycling is currently non-existent in the area of Sang Khom.

We determined that a landfill with greater environmental protection engineering would be the most cost-effective method of disposal for Sang Khom. We proposed to the Tambon Council that once the present dumping site is closed, an engineered landfill should be constructed. Such a landfill would protect the local environment through an engineered leachate collection system and a daily cover of soil being put on exposed waste in order to prevent disease vector access. We suggested to the council that the current site be slightly redesigned in the meantime in order to minimize the present environmental hazards. Re-landscaping the site would allow leachate to drain into a collection pit. We also suggested that open-air incineration be ceased and that exposed wastes be covered daily, or as often as possible, with soil.

Further suggestions to the council involved improvement of the tambon's solid waste collection practices. We proposed that the Tambon Council acquire lids for all waste bins that do not presently have them and attempt to use the current collection crew to pick up the litter on the roads.

The Tambon Council highly suggested to us that our proposal include methods to promote community awareness of the current problems and to promote participation at the family level in order to reduce the amount of waste disposed of at the landfill. They believed this would be beneficial to the community as a whole. The two methods of education that we proposed were a community workshop for adult members of the community and an in-school program to raise awareness in the students. The Tambon Council seemed enthusiastic about these two ideas, especially the school program because they believe that younger people of the village will be more willing to make changes in their opinions and habits of waste disposal. As this generation grows older, Sang Khom may see a dramatic improvement in the level of participation in the effort to improve the current waste disposal systems.

The council agreed with our project team that backyard composting is the most feasible personal waste reduction option for the villagers of Sang Khom. Considering that 90 percent of the population is involved in agriculture, and that the end product of composting can be used to fertilize soil, backyard composting was agreed to be a very practical option by the Tambon Council. The composting of organic waste could also reduce the volume of waste disposed of at the landfill by up to 60 percent.

Our proposal to the council also included suggestions for future projects that could be attempted when funds become available. These projects include the construction of the engineered landfill that has greater environmental protection engineering and the central collection of recyclables to be shipped to a nearby facility. The recycling option will only be possible when a buyer is located and is able to compensate Sang Khom for the losses acquired in collection and transportation of recyclables.

We offered possible sources of funding to the Tambon Council such as Thailand's National Environmental Fund of the Ministry of Science, Technology, and Environment. This fund has provided millions of dollars to other areas in Thailand for the purpose of constructing sanitary landfills. In an effort to begin collecting funds to improve the situation in Sang Khom, our team has already applied for a grant from the British Community in Thailand Foundation for the Needy and are waiting for a response.

Finally, we recommended to the council to seek to combine resources with a larger land area, such as the entire district of Sang Khom, as opposed to simply implementing a new system in one tambon. Some organizations feel that Sang Khom does not meet the requirements for funding because of its small size. However, if the Tambon Council proposed a project to construct a landfill that would support the entire district, funding organizations may be more willing to provide grants because the problem would be larger. If the Tambon Council attempts to seek grants from the government or other organizations, we suggested that they emphasize their willingness to combine with a larger land area and that the villagers are motivated to make any project self-sustainable.

After completion of our project, we came to the conclusion that this report could also be used as a guideline to perform other projects of a similar nature. In our report, we outlined the steps that our team took to complete our assessments. Assessing another village's current system could be done by obtaining a detailed physical description of the system and interviewing those involved in the management of the site. Assessing the feasibility of implementing a new system in another village could be done by comparing the cost-effectiveness, technical feasibility, and social and environmental implications of each system considered to be a possibility. It is our hope that a project such as this will be instigated in the future in hopes to help those villages with waste disposal problems similar to those encountered in the tambon of Sang Khom.

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1. Introduction

While Bangkok has developed rapidly over the past 50 years, much of Thailand still consists of low-income rural communities. These rural communities have observed the commercial and technological successes of Bangkok and have recently been attempting to develop along the same lines. Though some communities are developing successfully, this development has been unbalanced due to a lack of planning and foresight. Due to commercial development experienced throughout Thailand, the composition of the waste stream increasingly includes man-made items such as glass, plastics, and metals. The commercial development of the tambon of Sang Khom, Thailand, and the tambon's failure to dispose sanitarily of commercial waste products has prompted Thailand Senator Somkid Sreesangkom to initiate a project that aims to develop a more efficient, sanitary, and environmentally sound waste disposal system. The deficiencies of the current system may lead to the pollution of the environment, and could result in serious health problems for the local population in the near future.

This project was designed in an attempt to improve the current waste disposal system within the tambon[2] of Sang Khom, located in the province of Udon Thani, Thailand. The project team assessed the tambon's current waste disposal methods and the feasibility of alternate methods. This was accomplished by evaluating the tambon's available budget, analyzing the social and environmental implications of each method, and determining if the required technology and education would be available for the implementation of an improved waste disposal system. Once the study was completed, the team created a proposal for Senator Somkid that includes our recommendations for the most appropriate disposal method, the supporting analysis, and a discussion of how to implement the method. The three main objectives of the project were to evaluate the current waste disposal system of the tambon, to assess the feasibility of alternate waste disposal systems, and to create a proposal detailing our findings.

This report is organized as follows: background, methodology, results, analysis, and conclusions. The background chapter discusses all issues pertinent to waste disposal at our site and in other areas. First, we examine the culture and politics of Sang Khom, and Thailand as a whole, to provide an understanding of how these factors influence this project. Next, we discuss environmental regulations pertinent to waste disposal in Thailand and compare them to those of the United States to use as a basis for sanitation standards. We then discuss the current disposal methods of the tambon and modern methods used in the United States. The background section is followed by the methodology, which discusses the objectives of this project and how each objective was completed. The results and analysis chapter details our findings and their significance. We then utilized these results and analyses to form recommendations that were submitted to Senator Somkid

[2] Tambon is a Thai term referring to a community of villages. The tambon of Sang Khom is composed of twelve villages.

Sreesangkom and the Tambon Council. The full report was submitted to Worcester Polytechnic Institute in partial fulfillment of our degree requirements.

The desired effect of this project is to offer the Tambon Council the simplest and most affordable solution to the health and environmental problems associated with Sang Khom's current waste disposal system. Our team offered the Tambon Council some promising sources of funding. Our hope is that the council will consider the implementation of our recommendations and successfully do so in order to improve minimize the environmental hazards present in the current waste disposal system. During our study, we concluded that it would be technically and financially impossible to establish a waste disposal system that meets the extremely rigid sanitation regulations of the United States Environmental Protection Agency (U.S. EPA). We proposed a system that is significantly closer to these regulations than the present situation in the tambon. Even if only a part of our proposal is implemented, it would improve the sanitation of Sang Khom's solid waste disposal system.

2. BACKGROUND

This chapter introduces, defines, and discusses all topics that pertain to the project's objectives. Thai culture, politics and economics, environmental regulations, and waste disposal methods were essential topics to research in order to properly conduct this study. We present discussions of waste disposal methods used in Sang Khom and the United States.

2.1 The Kingdom of Thailand and the Tambon of Sang Khom

The area of study is the tambon of Sang Khom, one of six tambons in the district of Sang Khom, in the province of Udon Thani, in north eastern Thailand. Tambon Sang Khom is a community of 12 villages. One of the 12 villages within the tambon is also called Sang Khom. To avoid confusion, references to Sang Khom in this report signify the tambon as a whole, unless otherwise noted. According to a census of Sang Khom, at the beginning of 2002, there are 1,633 households, containing a total of 8,017 people. The annual rate of population growth is approximately 0.87 percent.[3] Later in this report we shall use this rate of population growth to estimate future waste disposal figures. Most of the tambon consists of farmland and 90% of the population is involved with farming. Fifty percent of the land is considered wetland.[4] The average per capita income is 28,000 Baht (637.74 U.S. dollars).[5]

Sang Khom has a few roads lined with markets and restaurants, but commercial or industrial developments are non-existent. The tambon has a modern hospital managed by the Thai Ministry of Public Health. Figure 1 depicts a map showing the location of Sang Khom in the northeast region of Thailand, close to the border of Laos. Figure 2 is a detailed map of the Thailand/Laos border and shows the location of Sang Khom in the province of Udon Thani.

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[3] This is a figure for all of north eastern Thailand. Phongphat, Seri & Kevin Hewison. Village Life: Culture and Transition in Thailand's Northeast. Pg. ix.
[4] Interview with Khun Poonsin Sreesangkom, the National Coordinator of the GEF(Global Environmental Fund)/Small Grants Programme in Thailand
[5] According to CNN's website, http://qs.money.cnn.com/tq/currconv/ , as of February 7, 2002, one U.S. dollar converted to 43.905 Baht.

Figure 1 - Map of Thailand border

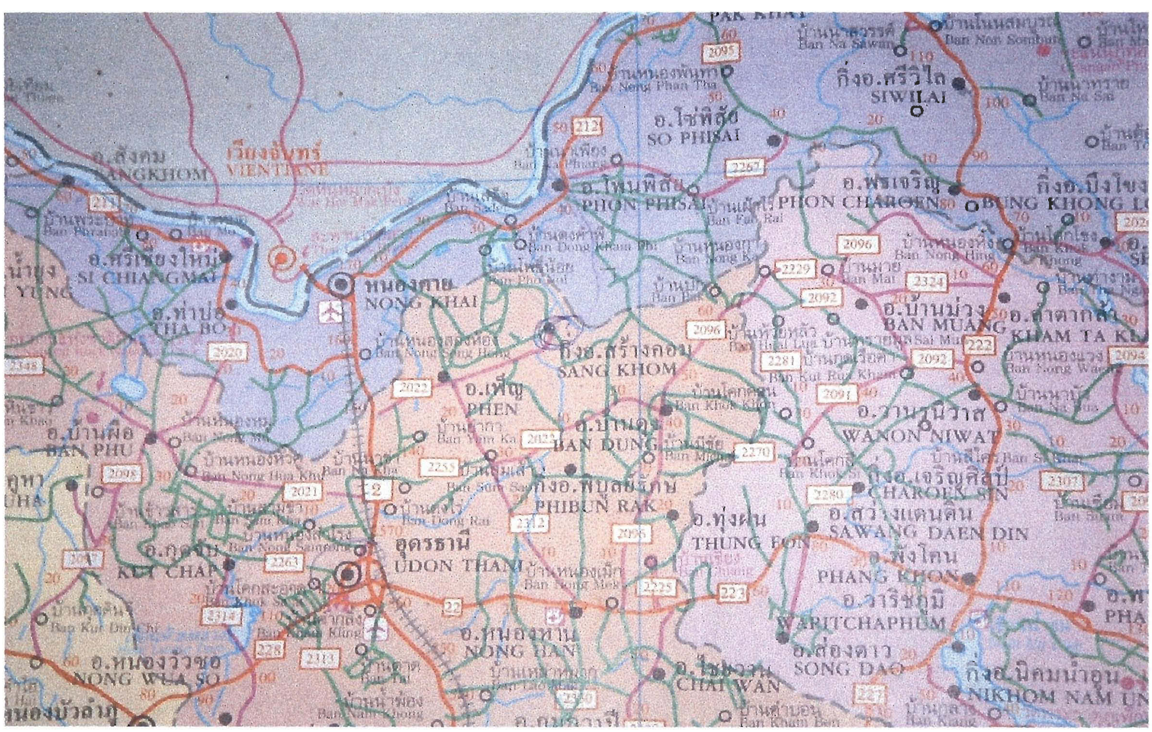

Figure 2 - Map of Thailand/Laos Border

Thailand, which was known as Siam until 1939, is now densely populated. As of July 2001, the population of Thailand was 61,797,751. The population density of Thailand was 120 people per sq km at this time. In comparison, the population density for the United States is 30 people per sq km, only one-forth the density of Thailand.[6] Approximately 21 percent of the Thai population lives in cities, and nearly half of these people live in Bangkok.[7] Since World War II, many Thai people have moved from the country to the city in search of better economic opportunities. Thai cultural attitudes and practices have changed since that time. Family planning has become a larger part of the Thai culture, and as a result, the average family size is currently falling.

According to the World Health Organization, approximately 59 percent of the Thai population has access to local health services, making Thailand the 75th ranked nation in the world for health service coverage. The U.S. is currently ranked 54th in the world.[8] This indicates that the health risks associated with the current waste disposal system of the tambon of Sang Khom may be taken seriously by the local government. For detailed demographic data of Thailand, see Appendix D-Thai Demographics.

Religion affects most facets of Thai life, especially in the rural areas. Theravada Buddhism is the predominant religion in Thailand, with approximately 95 percent of the population following this practice.[9] Theravada is a school of Buddhist belief that spread to Thailand in the beginning of the 13th century through Sri Lanka. This form of Buddhism combines different systems of religious practice and belief. Some of these systems include Hinduism, Christianity, and animism (the worship of objects and phenomena of nature). The essenense of this form of Buddhism is adherence to the middle path as espoused by the Buddha. By following the middle path, Thai people avoid all extremes in lifestyle and behavior. Among other religions in Thailand, Islam is practiced in the southern peninsula of Thailand, and there are some who practice Catholicism in the north.[10]

Central to the Buddhism are the Four Noble Truths. These truths state that desire and attachment are the cause of all suffering, and that people can take steps to free themselves from this self inflicted suffering.[11] The truths are as follows:

1. **The First Noble Truth**: Suffering is universally experienced.
2. **The Second Noble Truth**: Desire and attachment are the causes of suffering.
3. **The Third Noble Truth**: There is an end to suffering.
4. **The Fourth Noble Truth**: This end can be attained by journeying on the Noble Eightfold Path.[12]

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[6] Encarta: People and Society
[7] *Idem*
[8] *Idem.*
[9] *Ibid*, Religion
[10] *Idem*
[11] Buddhism 101
[12] *Idem*

The Eightfold Path is thought to result in faultless peace and unblemished happiness. These eight steps are detailed in Appendix F. The precepts in the Eightfold Path require people of the Buddhist religion to abstain from:

1. Harming living beings
2. Taking what has not been given
3. Having improper sexual relations
4. Giving false and incorrect speech
5. Using intoxicants excessively (alcohol, drugs, etc.)[13]

When assessing the feasibility of alternate waste disposal systems, it is important to know how religion and culture could affect our proposal. After evaluating the beliefs of Buddhism, the most relevant issue that could be related to waste disposal systems is harming of living beings. The two current methods of waste disposal can indirectly hurt the environment and harm living beings in the environment.

To implement improvements to the waste disposal system, local officials of may need to educate the villagers about the problems of the current system and the proposed solution. An estimated 99 percent of Thailand's population is literate. The high rate of literacy suggests that pamphlets and newspaper articles may be options for communicating proposed changes to villagers. However, written documents of this type may not achieve a high level of participation in any proposed system. In an interview, Poonsin Sreesangkom[14], the national coordinator of the Global Environmental Fund/Small Grants Programme in Thailand, said that the villagers from the Isarn tend to be stubborn when it comes to change. He recommended workshops and training sessions as the best methods to communicate our findings and recommendations to villagers. Khun Poonsin also stated that the elders within the tambon would be more resistant than the younger villagers. He suggested that Tambon Council begin the education process with the students in schools. Students may be more effective in explaining to their parents the benefits of proposed changes, rather than foreigners telling them what is wrong and how it should to be changed.

Recently, Khun Poonsin was involved in a project, funded by the GEF/Small Grants Programme and the Ministry of Education, to promote backyard composting in five villages throughout Thailand. Each project, completed by July of 2000, was implemented through the local school. The process began with training the teachers in the methods of backyard composting. The teachers then trained their students, who then convinced their parents to begin composting at home. According to the project's final report, the use of schools to promote backyard composting was a success.[15]

Khun Poonsin discussed other personality traits of the Isarn villagers. He mentioned that part of the Thai mentality is "wait and see". For example, most villagers would wait for a few families to establish a backyard compost heap. Then, if they believed that their neighbors were successful, they would be more

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[13] *Idem*

[14] Poonsin Sreesangkom is the nephew of Senator Somkid Sreesangkom.

[15] Loei River Conservation Report

likely to try composting. Such an establishment of backyard composting would be slow and trying due to this mentality. Khun Poonsin mentioned that if the villagers were mandated by the Tambon Council to participate in the new waste disposal system, whether this participation involves active participation or simply a heavier tax burden, they might complain, but they would comply for the good of the village.

Khun Poonsin also discussed the changing patterns of consumption among the Isarn villagers that have contributed to present waste disposal problems in the tambon of Sang Khom. Up until the last 50 years, villagers of the Isarn had depended on agricultural occupations for their livelihood, cultivating rice and harvesting fish and shellfish from the local waters. In the north, these occupations were accompanied by collection of forest resources, such as timber and food for dry seasons. In rural areas, such as Sang Khom, the pattern of life is governed by monsoons and by seasonal religious festivals. Currently, the Thai have become more urbanized and are focusing more on commerce and trade. [16] This commercialization has altered the composition of rural communities' waste stream, as it has done in the tambon of Sang Khom. Waste streams now include an abundance of plastics, metals, and glass. The composition of Sang Khom's solid waste is discussed later in Section 2.4. Khun Poonsin also mentioned that villagers of the Isarn are becoming more materially oriented. According to Khun Poonsin, they prefer to use a polluting motorcycle over a bicycle, even if the distance traveled is relatively short. Also, they have begun to package food with plastic rather than the classic Thai packaging materials, like banana and bamboo leaves, which have no harmful impact on the environment when disposed. All of these statements held true when we observed the village for a period of four days. This new materialism has extended to rural Thailand and is causing an increase of waste generation. The tambon villagers do not hesitate to discard solid wastes that could be recycled in some fashion to benefit the community and the environment. Recycling is a broad term that includes systems beyond that of recycling of metals, glass, and plastics. Other forms of recycling are discussed in Section 2.4.

When working with Thai people, it was important not to emulate the professional, "all business" attitudes found in American businessmen. Thai people do not like to be under pressure, or rushed when doing work. The Thai word for work, *ngan,* means both 'work' and 'party'.[17] This was evident during some of our interviews, where we were offered local food and drink. Even while walking along the streets of Sang Khom, our group was invited to partake in meals by some of the villagers.

2.2 Government, Politics, and Economics in Thailand

In an interview, Poonsin Sreesangkom mentioned that the nation's central government has not made environmental protection and promotion a financial priority. He claimed that the government's primary objective has been to improve the nation's infrastructure. While this is an important aspect of

[16] *Ibid*, Way of Life
[17] Robert & Nanthapa Cooper. Culture Shock Thailand. Pg 129.

industrialization, projects concerning the environment have rarely received funding. The political bodies that we investigated for potential support of this project are the Ministry of Science, Technology, and Environment (MOSTE), the Education for Development Foundation (EDF) under the chairmanship of Senator Somkid Sreesangkom, and The British Community in Thailand Foundation For the Needy.

MOSTE was known as the Ministry of Science and Technology until April 1992, when the "Enhancement and Conservation of National Environmental Quality Act" established three organizations to monitor and protect Thailand's environment while promoting environmental awareness. With this act, "Environment" was added to the end of the Ministry's title. The three organizations established under the act are:

1) Office of Environmental Policy and Planning (OEPP) [18]. This organization manages the country's natural resources and encourages national sustainable development. The Environmental Policy and Planning Division of the OEPP is responsible for formulating and evaluating environmental policies, plans, and strategies.

2) Department of Environmental Quality Promotion (DEQP).[19] This organization's mission is to raise environmental awareness, promote public participation, conduct research and development, and develop appropriate technologies for the enhancement of the national environment.

3) Pollution Control Department (PCD).[20] This organization is responsible for:
   a) Establishing environmental quality and emission/effluent standards. These environmental quality standards includes those for water quality, air quality, noise pollution, hazardous substances and solid waste.
   b) Monitoring the national environmental quality.
   c) Formulating plans to control, prevent, and remedy environmental problems caused by pollution.

The Education for Development Fund (EDF) is a government-run organization and is chaired by Senator Somkid. The EDF has existed as a public charitable organization since 1988. Its primary objective is to enable children from lower-income families to continue their education beyond the elementary level. Specifically, the EDF awards scholarships that enable these children to complete the three-year course of junior high school. The EDF has been able to award over 137 million baht (3.11 million U.S. dollars) in scholarships due to donations from foreign organizations and from local fund-raising. In our coorespondence with Khun Francesca Sreesangkhom[21], she stated that it may be possible to request funding for this proposed project if it is related to the education of the youth in Sang Khom. A discussion of how education of the youth is crucial to this project is included in the results and analyses section. See Appendix C-Information on Organizations Connected with the Project for EDF contact information.

A description of the structures of Thailand's central and local governments allow for an understanding of Senator Somkid's role within the government. Thailand has a constitutional monarchy, in

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[18] http://www.oepp.go.th
[19] http://www.deqp.go.th
[20] http://www.pcd.go.th
[21] Senator Somkid's wife who was our contact with the senator

which the monarch serves as the moral leader for the people.[22] King Bhumpol Adulyadej has great political influence and holds limited power over the legislative branch. The King has the ability to dissolve the national assembly and order new elections. He can also appoint officials that hold legislative and executive power. Figure 3 depicts the organizational structure of Thailand's governmental hierarchy.

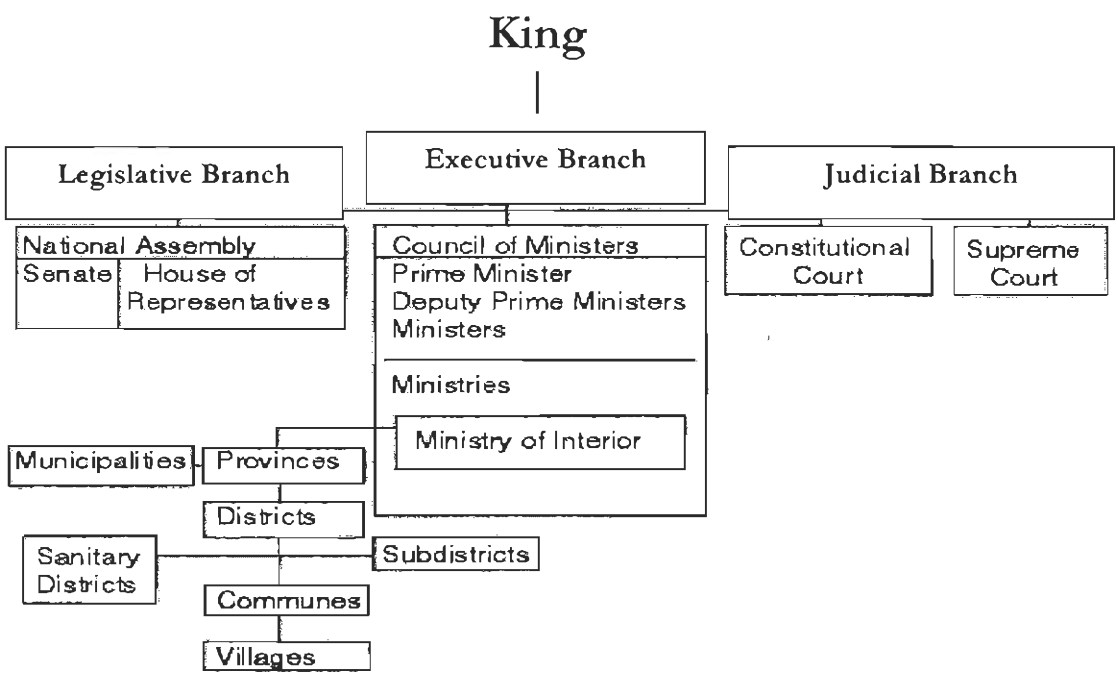

Figure 3 - Flow chart of monarchy system[23]

The National Assembly holds Thailand's legislative power, and through its appointment of the Prime Minister, executive authority.[24] The National Assembly is composed of a House of Representatives and a Senate. The House of Representatives of Thailand is composed of 500 elected members whose term of office is 4 years. The Thai House of Representatives has a similar function to the House of Representatives in the United States in that it must approve legislation.[25] All bills must be first approved by the House before they are sent to the Senate. Money bills must also be first approved by the Prime Minister. The Senate is composed of 200 elected members whose term is 6 years. The Senate is analogous to the U.S. senate, but the Thai Senate cannot generate legislation, and can only delay passage of legislation approved by the House of Representatives. The National Assembly elects the Prime Minister who officially holds executive power in Thailand and has the privilege of appointing heads of cabinet departments.[26] The current Prime Minister is

[22] Thailand: a country study, pg 178.
[23] *Ibid.*, pg 55.
[24] This information comes from the Constitution of the Kingdom of Thailand, 1997.
[25] Modern Thailand, pg 50.
[26] http://www.thaigov.go.th/index_eng.htm

Thaksin Shinawatra one of the country's richest businessmen. Thailand has an extensive government bureaucracy, which actually has stronger executive power than the National Assembly.[27]

In the tambon of Sang Khom, the highest governing body is the Tambon Council. It is composed of two elected representatives from each of the 12 villages. The Tambon Council acts as an executive and legislative body and convenes monthly to discuss local problems and create policy for the tambon. In particular, the Tambon Council was responsible for creating the policy for the solid waste management and was responsible for establishing the current system. In an interview with the council members, it was clear that they desire to improve the sanitation of the waste disposal system, but felt that the current budget is insufficient for the purchasing of major equipment. Also, there have been more urgent problems in the tambon that have drained the budget and have caused waste disposal problems to be placed in the backgroud. For this reason, a project was requested by the senator of Sang Khom, Senator Somkid Sreesangkom. The total yearly budget for the tambon is only 1.2 million baht, which equates to 27,270 U.S. dollars. The tambon council collects a total of 2.4 million baht per year from the villagers and sends this money to the central government. The 1.2 million baht is then returned to the tambon as a government subsidy to be used for the management of roads, water, electricity, tambon workers' salaries, as well as waste disposal. The tambon council reported that Sang Khom has never had a surplus from this budget and cannot affort an expensive solid waste disposal project. In addition, the council mentioned that they have not been able to improve the sanitation of solid waste disposal due to a limited knowledge of waste disposal systems as well as their limited budget.

2.3 Environmental Regulations Pertaining to Waste Disposal

It is evident that the central government is taking into account the environmental aspects of industrialization and technological advancement. In 1992, the Enhancement and Conservation of National Environmental Quality Act (NEQA) was passed[28]. This act outlines the guidelines for the protection of Thailand's environment and the promotion of environmental awareness. The issues covered by these guidelines include the location of a garbage disposal facility, where extra funding for a construction of the facility can be found, and restrictions on who is allowed to oversee a new facility. The sections of this act that we were concerned with were those specifically pertaining to waste disposal. In the introduction to the act, waste is defined as "refuse, garbage, filth, dirt, wastewater, polluted air, polluting substance or any other hazardous substances which are discharged or originated from point sources of pollution, including residues, sediments or remainders of such matters, either in the state of solid, liquid, or gas."[29]

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[27] Modern Thailand, p. 51.

[28] http://www.deqp.go.th/english/laws/index_law.htm, Enhancement and Conservation of National Environmental Quality Act

[29] *Ibid,* Definitions

The King of Thailand and the National Legislative Assembly laid out plans for an environmental fund in Chapter II of the Enhancement and Conservation of National Environmental Quality Act. In Section 23 of this chapter, it is stated that distributions of this fund will be made "as grants to government agency or local administration for investment in and operation of…[a] central waste disposal facility, including the acquisition and procurement of land, materials, equipment, instrument, tools and appliances necessary for the operation and maintenance of such a facility."[30] A request for this funding is crucial because Sang Khom's budget does not meet the financial requirement for the implementation of a new waste disposal system. These funds can also be in the form of "loans to local administration or state enterprise for making available … waste disposal facilities to be used specifically in the activities of such local administration or state enterprise." The act also states that such loans can be given to "private person[s] in case such person[s] [have] the legal duty to make available and install an on-site facility as [their] own for the treatment of…waste disposal or any other equipment for the control, treatment or eliminate pollutants that are generated by his activity or business undertaking, or such person is licensed to undertake business as a Service Contractor to render services of…waste disposal under this act."[31] With the approval of MOSTE, the local administration of Sang Khom can borrow from this environmental fund to finance the construction of a new disposal facility.

Chapter III, Part 2 of this act, entitled Environmental Quality Management Planning, states that another piece of legislation, the Changwat Action Plan, provides a plan for determining the severity of problems in specific land areas of Thailand. This act addresses issues such as a "plan for procurement and acquisition of land, materials, equipment, tools and appliances which are essential for the construction, installation, improvement, modification, repair, maintenance and operation of…central waste disposal facilities belonging to government agency or local administration concerned" and a "plan for collection of taxes, duties and service fees for operation and maintenance of…central waste disposal facilities referred to in [the section aforementioned]."[32] It would be necessary to contact government officials who are put in control of this plan to determine what lands are available for the installation of a waste disposal facility.

Chapter IV, entitled Pollution Control, the NEQA states in Section 78 of Part 6, "…the collection, transport and other arrangements for the treatment and disposal of garbage and other solid wastes…shall be in accordance with the governing laws related thereto."[33] Few specific environmental regulations pertinent to waste disposal were found in this chapter. From a report, produced by the Pollution Control Department in January of 2002, entitled "Pollution from Solid Waste and Night Soil", we concluded that Thailand does not

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[30] *Ibid,* Environmental Fund
[31] Improper grammar comes from the translation
[32] *Ibid,* Environmental Protection
[33] *Ibid,* Pollution Control

have any legal regulations pertaining to incineration.[34] Evidence to support this claim comes from a section entitled 'Legal Guidelines' that included these statements:

1. "Establish solid waste disposal site pollution control standards, i.e. effluent standards and stack emission standards from solid waste and crematory incinerators."
2. "Designate solid waste and night soil disposal facilities as pollution source, with emission and effluent controlled according to established standards." No mention of where these standards originate was mentioned.
3. "Establish monitoring systems to record the pollution situation from pollution sources." [35]

The report included goals that we have included here to be used as guidelines for our proposal. One goal is to reduce or control solid waste generation to the rate of not more than 1.0 kg/person/day. The waste disposal rate for the tambon of Sang Khom is detailed in Section 4.1 Evaluation of the Current Waste Disposal System. Another goal is to have Bangkok and communities throughout the country utilize waste of not less than 15 percent recycled materials. A final goal is to ensure that each province has a master plan for sanitary solid waste and night soil (sewage) disposal, and every municipality and sanitation district have proper solid waste and night soil disposal systems.

Management guidelines to achieve these goals were to:

1. Financially penalize all polluting individuals and organizations
2. Manage solid waste facilities at the provincial level
3. Encourage private sector to provide services for solid waste collection
4. Encourage provinces to prepare suitable land for long-term disposal of solid waste, including designating areas reserved for disposal of refuse in the city plans
5. Require producers to buy back used packaging from consumers for disposal or recycling; specify product and packaging types that producers must reclaim in order to reduce the quantity of solid waste

In a section entitled 'Investment Guidelines', the following policies proved pertinent to our attempts to produce a proposal that requests funds from governmental organizations:

1. Invest in construction of hygienic solid waste and night soil disposal facilities and providing suitable equipment by means of: joint ventures between the central government and the private sector, the central government providing the total budget, or subsidizing part of the budget to local governments to implement.
2. Promote investment and provide incentives to the private sector that provides services or public service organizations which have operations that are related to the management of solid waste, including recycling.
3. Establish central solid waste and night soil disposal facilities that provide services to several communities in close proximity to one another.
4. Improve and rehabilitate existing unhygienic solid waste disposal areas in communities throughout the country according to a prioritization of problems.

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[34] Night Soil refers to human sewage.

[35] http://www.pcd.go.th. (January 15, 2002)

The third point could be especially important because Sang Khom is a relatively small area. If we propose that a larger area that including multiple tambons, the organizations and foundations which might supply funds may be more willing to subsidize the effort.

The only specific regulations that could be found pertaining to solid waste disposal are those regarding water quality. Water quality standards have been found for the categories of drinking water, groundwater, and surface water. Details of these standards can be found in Appendix J – Drinking Water Quality Standards.

Regulations for solid waste disposal in the U.S. were more abundant and readily accessible. The U.S. Environmental Protection Agency established the *Solid Waste Facility Criteria*[36], in which there are six issues that must adequately be considered in order for a landfill to be considered sanitary:

1. **Floodplains, surface water, and groundwater.** Facilities cannot be built in a floodplain area. A floodplain is a low-lying area where water collects from precipitation and from ground water sources. The current facility was not built in a floodplain, so this is not a cause for concern. The guidelines also state, "no facility may contaminate an underground drinking water source."[37]
2. **Air.** No open burning of solid wastes is allowed, though periodic burning activities are allowed. This criterion is cause for concern because Sang Khom does indeed burn its waste during the dry season.
3. **Farmland.** No solid waste is allowed to be within one meter of land used for farming. Compliance with this regulation should be relatively easy in the tambon.
4. **Endangered species.** A facility cannot interfere with the habitat of any endangered animals species.
5. **Disease.** The facility operators are in charge of eliminating disease vectors, such as rodents and insects, by a daily covering of the landfill. The covering specifications are discussed in Section 2.4.3.4
6. **Safety.** The final criterion states that gases made by the waste need to be kept under a particular limit for the safety of those living near the facility and the safety of wildlife.

Guidelines for environmentally sound incinerators are not included here because, as will be discussed later, an expensive incinerator is not feasible for an area as small as the tambon of Sang Khom. For a discussion of U.S. EPA incinerator operational regulations see Section 2.4.3.3 Incineration. In that section we detail an interview with the Environmental, Health and Safety Director of the Millbury Incinerator, in the state of Massachusetts, which offered information about the facility's environmental controls that are mandated by the U.S. EPA.

2.4 Garbage Disposal Methods

The following section discusses the current waste disposal methods of the tambon and alternate methods that our team has hypothesized to be options for the tambon. All topics pertinent to the methodology of evaluating the current methods and assessing alternative methods are discussed or defined

[36] Deborah Hitchcock Jessup, pg. 55
[37] *Ibid*, p.56

here. The domain of inquiry of this project is the disposal of household wastes. Concerns associated with commercial wastes will not be discussed, as there are no large-scale businesses or factories located in the tambon.

2.4.1 Solid waste collection methods in the U.S. and in the tambon of Sang Khom

Background information on standard U.S. waste collection practices, along with a basic description of the tambon's collection system, is necessary to determine comparatively the system's levels of efficiency and sanitation. Over the past few decades, the waste collection practices in the U.S. have remained virtually unchanged. Nearly 60 percent of towns with populations between 5,000 and 10,000 have their household garbage collected once a week.[38] Trucks have a carrying capacity of 4 to 5 metric tons in a 14 to 18 cubic meter bed. To learn about U.S. collection practices, we interviewed the Worcester Department of Public Works, in Massachusetts. According to Joseph Picard, there are nine truck routes in Worcester, and each route is performed once per week.[39] The crew size is two men and the trucks can carry an average of ten tons of waste. This amount of waste would require trucks with greater volume capacity than the standard trucks mentioned above. These trucks take the waste to an incinerator facility that is six miles away. As is discussed in Section 2.4.3.3 Incineration, incineration is most common waste disposal system used by cities.

In the tambon of Sang Khom, a team of four garbage collectors work daily. Because only two to three villages' garbage is collected in one day, the pick-up crew requires four to six days to complete the collection of waste for the entire tambon. This pick-up is more frequent than it is in the United States. In order for solid waste to be collected from a household, it must be contained in a local government-owned bin. There are 2,000 of these bins in the tambon, which are rented from the local government and maintained by private families, markets, businesses, and the local hospital. The rent is variable: a household must pay 10 baht per month, markets and businesses must pay 20 baht per month, and the hospital must pay 200 baht per month. Sang Khom collects approximately 90,000 Baht (2,000 U.S. dollars) per year from bin taxation.[40]

These bins are constructed of recycled rubber from automobile tires, and cost 350 baht (8.00 U.S dollars) each. All bins currently being made are supplied with covers. When bins were first distributed, covers were not always supplied. Through our own observations, nearly all of the bins remain uncovered. Because of this, disease vectors such as rats, insects, and birds could have access to daily garbage. A disease vector is a potential carrier of pathogens.

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[38] E.S. Savas. The organization and efficiency of sold waste collection. P. 58.
[39] Joseph Picard is the manager of Worcester's Municipal Solid Waste Collection Organization
[40] Interview with Tambon Council of SangKhom

The four-person team is responsible for the daily collection of waste, using a small truck with a volume of 6.2 cubic meters. One man drives and the other three men help to empty the waste containers. Two of the four men are classified as drivers and earn 4,100 Baht (93 U.S. dollars) per month, while the other two men are classified as collectors and earn 3,000 Baht (68 U.S. dollars) per month. The following figures are photos of the collection truck and the collection bins.

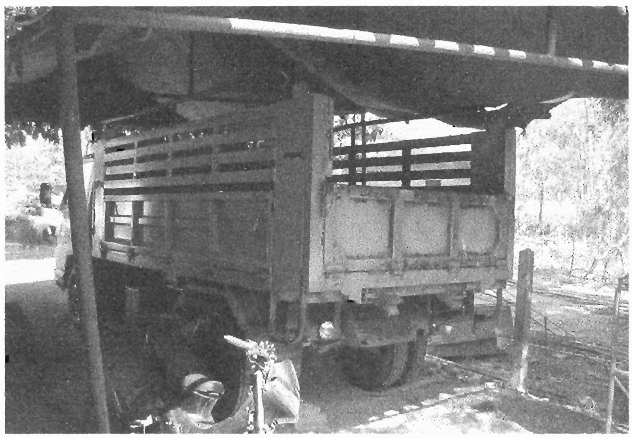

Figure 4 - Sang Khom's Isuzu solid waste collection

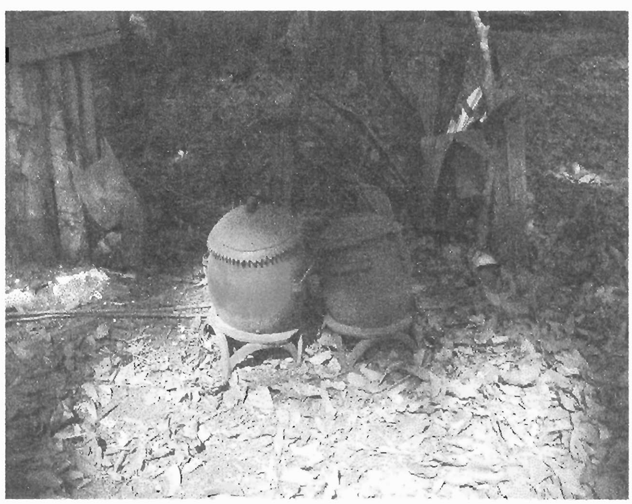

Figure 5 - Rubber collection bins for solid waste

When comparing the tambon's system to the United States' system, differences are apparent in the frequency of pickup and number of workers in a truck team. As part of the project, we determined the reasons for these differences, and how the efficiency of tambon's system compares to the systems utilized in the United States.

2.4.2 The tambon's current system of waste disposal

The tambon uses two methods to dispose of its garbage: open dumping, and open-air incineration. The initial information about the tambon's waste disposal systems is included here to introduce the possible health and environmental problems that are associated with these methods. The current method of open dumping of solid waste is an outdated means of organized waste disposal. For the tambon, garbage is dumped into a 20x30x3 meter pit that was dug on high ground five kilometers from the village of Sang Khom. In fact, the pit is not even located in the tambon of Sang Khom, and is nearest to the village of Ban Khok, part of the tambon of Phen. The village of Ban Khok village is only 1.6 kilometer south of the pit. The current pit was constructed approximately three years ago. The previous waste disposal site was constructed and operated in the same fashion, but was built at a site located less than 200 meters from surface water, and was not significantly elevated from the water. Complaints from villagers about foul odor and the possibility of surface water contamination convinced the Tambon Council to relocate the dumping site.

Figure 6 and Figure 7 are photos of the current and previous dumping sites, respectively.

Figure 6 - Open dumping site of Sang Khom

Figure 7 - Previous dumping site with view of surface water

Note in Figure 6 that the burning waste is not engulfed with flames, but merely smoking. This smoking results from incomplete combustion, which releases in toxic emissions, as discussed in subsequent paragraphs. Note in Figure 7 the close proximity of the surface water with respect to the pit in the foreground, where waste is now buried. The problems observed with these waste disposal methods are detailed in the results and analysis section. When household wastes are disposed of into an open pit, the organic wastes, under warm moist conditions, "become ideal breeding places for disease causing organisms."[41] Pathogens, even if absent initially, can access the garbage through mammals, birds, and insects. Diseases that are most commonly transmitted by these organisms include gastroenteritis, dysentery, hepatitis, and encephalitis. Symptoms of gastroenteritis include a one to two week episode of diarrhea, vomiting, and fever. The main symptom of dysentery is excessive diarrhea. Hepatitis A is recognized by excessive fatigue and liver disease. Symptoms of encephalitis include fever, malaise, and cerebral dysfunction.

One environmental concern the current waste disposal system is the possibility of ground or surface water contamination by a leachate. Leachate is composed of water, dissolved solids, and other organic liquids that flow through the garbage due to gravity. The hazards of the leachate stem from soluble salts and toxic organics. Leachate can pollute water by flowing on the surface of the ground and either evaporate or enter local surface water. Leachate can also be absorbed into the ground and migrate into underlying ground water. In this second case, pathogenic microorganisms are removed from the leachate by the successive soil layers. If the groundwater table is close to the surface, and the water is a drinking water source, the villagers' well water could potentially contain toxic chemicals. Fortunately, pathogens cannot migrate with the leachate through the earth, so the well water would not contain the bacteria that are flourishing in the pit. If the leachate is not absorbed into the ground, it can run off into nearby surface water. This would contaminate the surface water not only with toxic chemicals, but also with disease-causing pathogens. Figure 8 illustrates

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[41] Henry J. Glynn, Environmental Science and Engineering. Pg 557.

the different ways that humans can be affected by toxic chemicals and pathogens that originate in improperly disposed solid waste.

To determine if the villagers' drinking water is contaminated by the leachate, we found what chemicals are commonly found in leachate and what their acceptable limit is in drinking water. Table 1 details the metals and anions commonly found in leachate and their limits for drinking water. The table shows that the levels of toxic components can become quite high in a relatively short amount of time. In Sang Khom, the waste disposal site was constructed to have a lifespan of seven years. The levels of lead, cadmium, and mercury within the local drinking water are discussed in Section 4.1.3.2

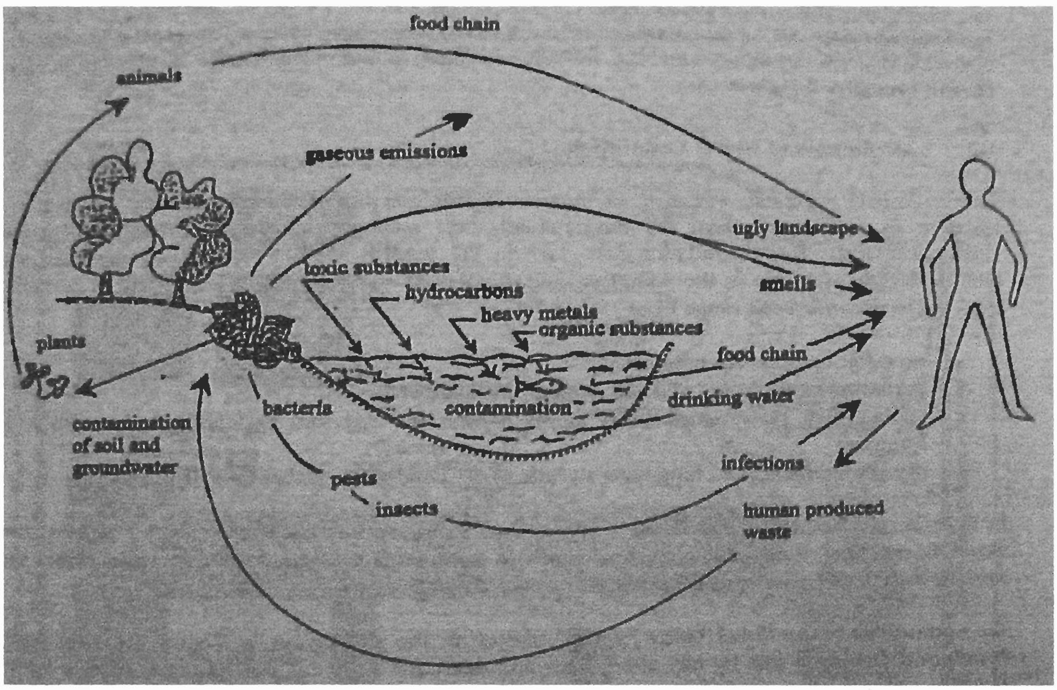

Figure 8 - Toxic chemicals routes from solid waste to the human body[42]

Component	Conc. of 1-2 year old leachate	Typical Drinking water standard
	Mg/L	Mg/L
Calcium	1000-3000	500
Sodium	1000-3000	20
Magnesium	500-1000	-
Potassium	500-1000	-
Iron	500-1000	0.03
Aluminum	100-200	0.1
Zinc	100-200	5
Copper	<10	1
Lead	**<10**	**0.05**
Cadmium	**<1.0**	**0.005**

[42] World Bank. Solid Waste Landfills in Middle- and Lower-Income Countries. Pg. 9

Chloride	1000-3000	250
Bicarbonate	1000-3000	-
Sulfate	500-1000	500
Phosphate	50-150	-

Table 1 - Constituents of 1-2 year old leachate and drinking waste standards. [43]

The tambon's secondary means of waste disposal is open-air incineration. As seen in Figure 6, open-air incineration of waste is performed at the waste disposal site. Open burning of household wastes can heavily pollute the air with harmful dioxins, hydrochloric acid, and particulate mater. The plume of smoke given off by the burning waste contains ash particles that can be very harmful to the lungs if inhaled. This open burning method results in uncontrolled and incomplete combustion. The combustion is incomplete because not enough oxygen is available to the burning pile, which leads to the formation of carbon monoxide gas. If the level of oxygen was sufficient, all combustion would result in the emission of carbon dioxide and water. But this is not the case; toxic gases are released during the combustion of household wastes including sulfur oxides, nitrogen oxides, hydrogen chloride, and various hydrocarbons.[44] This form of incineration is harmful to the local population, harmful to the environment, and does not meet the pollution standards of the U.S. EPA. Environmentally friendly incineration options are discussed in Section 2.4.3.3 Incineration.

2.4.3 Applicable municipal solid waste disposal methods.

In this section, we discuss the waste disposal methods of incineration, composting, recycling, and land filling in order to introduce possible alternatives to the open dumping and open-air incineration methods described above. The benefits and drawbacks of each alternative method are discussed to offer a basis for comparison. Information and data concerning the appropriate types of waste handled by each system, the environmental and health problems associated with each system, required land and equipment and capital costs for each system are also discussed. A general discussion of non-toxic garbage disposal in the United States precedes the detailed descriptions of each system.

In 1989, the U.S. EPA created a hierarchy of the best ways to dispose of solid waste. These methods, listed in order of decreasing preference, are source reduction (reuse of products and backyard composting), materials recycling and municipally-run composting, incineration with energy recovery, and sanitary land filling.[45] The first item is a personal waste reduction item, and is not discussed in this section because it is not a municipally-run system. It is considered the most environmentally friendly option because virtually no equipment is required to participate in this option. Though many in the U.S. believe that materials recycling and municipally-run composting facilities are environmentally benign, they are listed second on the chart because the collection and transportation of waste material, the sorting and shipping of

[43] Edward A. McBean. Solid Waste Landfill Engineering and Design. Pg. 297.
[44] Pavoni. Handbook of Solid Waste Disposal. Pg. 115.
[45] Henry, J. Glynn. Environmental Science and Engineering. Pg 567.

materials, and the processes used to convert the materials into useable products can pollute the air and water. Recycling and municipally-run composting systems can only handle limited types of waste as well as not being completely environmentally benign. Incineration is listed above land filling because it can be environmentally sound if proper emission controls are in place to prevent air pollution. Unfortunately, this method is usually quite expensive. A sanitary landfill is usually the simplest and cheapest to maintain, but it is more likely to pollute the environment if care is not used to engineer and maintain a landfill. Figure 9 illustrates the four classes of municipally run solid waste management and disposal listed above.

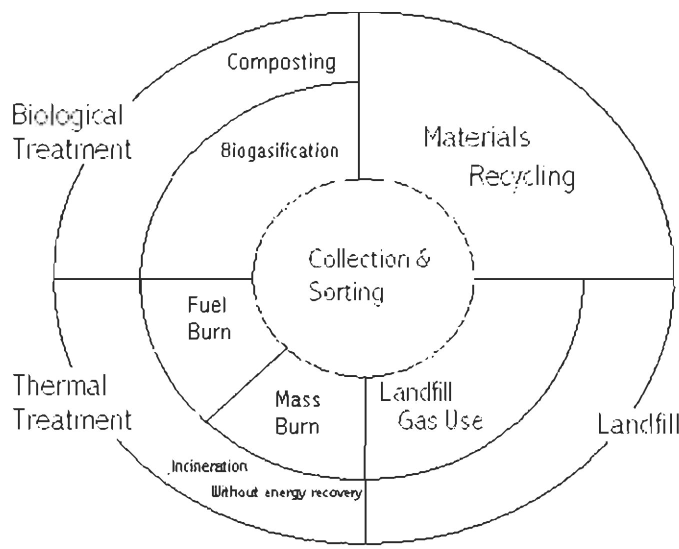

Figure 9 - The integrated waste management system.[46]

This figure displays all possible options for solid waste management including energy recovery, which makes up the middle, three-quarter circle.

Before proposals for new waste disposal systems are made, it is important to understand what methods are most acceptable in the U.S. compared to the methods that are the most acceptable in Thailand. According to the textbook Environmental Science and Engineering (1993), 67 percent of all U.S. municipal solid waste is land filled, 16 percent is incinerated, 15 percent recycled, and 2 percent composted.[47] In Bangkok, Thailand, 71 percent of the collected solid waste is land filled, 16 percent is composted, and 13 percent was left at factories to "decompose"[48]. Although incineration has never gained popularity in the Bangkok metropolis, the percentage of waste being composted is much higher.

To determine the appropriate method for waste disposal in a village community, the volume and content of the waste to being disposed must be assessed. A 1993 report on solid waste management in the

[46] Dr. Vanee Komolprasent. Waste Recycling.
[47] J. Glynn Henry, Environmental Science and Engineering. Chapter 14.
[48] Pollution from Solid waste and Night Soil. http://www.pcd.go.th

city of Chiang Mai, Thailand contains waste stream composition for the province. This only waste composition data found for any area in Thailand. Because most of Chiang Mai Province is rural, we have assumed that the waste stream composition is similar to that of Sang Khom. This data would be a worst-case scenario for the tambon of Sang Khom because Chiang Mai's waste stream includes commercial and industrial waste. Using this data, we were able to evaluate and plan for the waste composition found in Sang Khom. Using the statistics in the report, we created a pie chart to depict the composition of the waste produced by the city of Chiang Mai, labeled Figure 10. Note the high food and recyclable content of the waste stream despite the commercial and industrial factories.

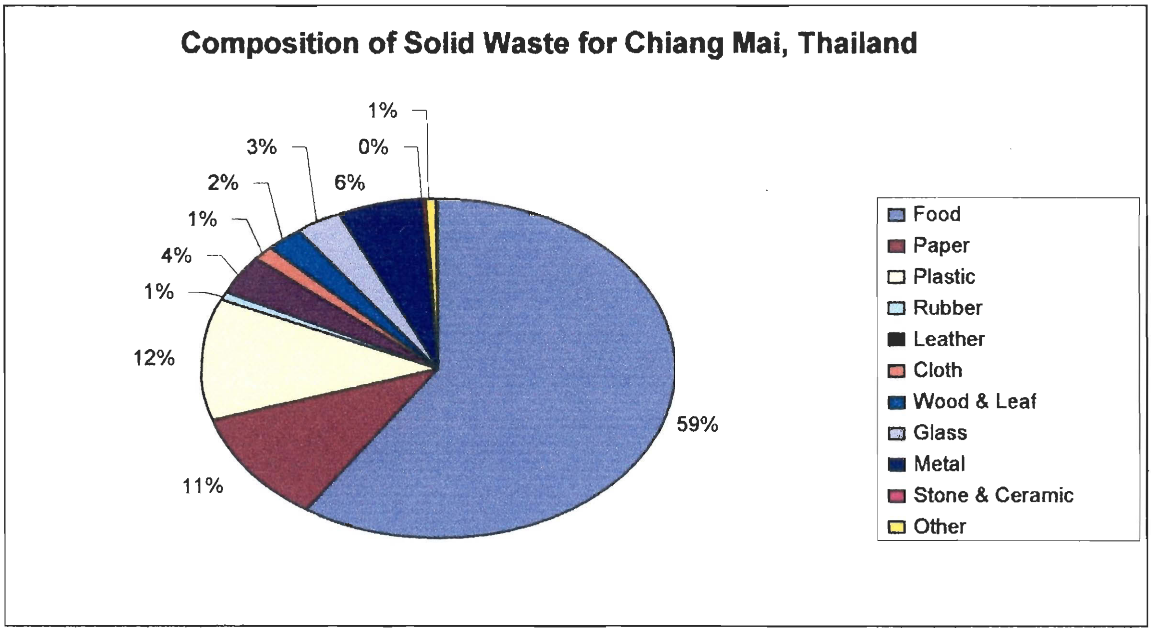

Figure 10 - Composition of solid waste for Chiang Mai, Thailand[49]

This chart indicates that composting and recycling waste could be effective options to reduce the amount of waste that is being disposed of in a landfill. To effectively compare waste disposal methods for the U.S. with those of rural Thailand, Table 2 provides statistics on household wastes in various income nations.

	Lower-Income Countries	Middle-Income Countries	High-Income Countries
Waste generation (kg/cap/day)	0.4 – 0.6	0.5 - 0.9	0.7 - 1.8
Waste densities(wet weight basis kg/m)	250 - 500	170 – 330	100 - 170
Moisture content (% wet weight)	40 - 80	40 – 60	20 - 30
Ranges of compositions (% by wet weight)			
Paper	1 - 10	15 – 40	15 - 40
Glass/Ceramics	1 - 10	1 – 10	4 - 10
Metals	1 – 5	1 – 5	3 - 13
Plastics	1 – 5	2 – 6	2 - 10
Leather/Rubber	1 – 5	-	-

[49] Dr. Frank Kreith, Course Notes for a Workshop on Solid Waste Management. Oct. 1993.

Wood/Bones/Straw	1 – 5	-	-
Textiles	1 – 5	2 – 10	2 - 10
Vegetable/Putrescible	40 - 85	20 – 65	20 - 50
Miscellaneous inert materials	1 - 40	1 – 30	1 - 20
Particle size = 10mm	5 - 35	-	10 - 85

Lower-Income Countries had a per capita income of less than $360 in 1978
Middle-Income Countries had a per capita income between $360 and $3,500 in 1978

Table 2 - Statistics on waste.[50]

The tambon's waste is comparable to lower-income or middle-income countries due to the per capita income. Data on moisture content is pertinent to the discussion of incineration because high water content waste does not easily combust. The high vegetable and putrescible content is pertinent to the discussion of composting because these items biodegrade rapidly. The high density of this waste pertains to the discussion of land filling and will be used to determine the volume required to bury the waste of Sang Khom.

2.4.3.1 Municipally operated composting facilities

Two types of composting may be viable options for the tambon: backyard composting or a municipally operated composting facility. Backyard composting is a personal waste reduction option and is discussed in Section 2.4.5 Waste reduction options. According to the U.S. EPA waste disposal hierarchy, a municipal composting facility ranks is better for the environment than incineration or land filling, and second only to waste reduction. The composting process is simple; the organic waste is piled and water is occasionally added to the pile. To increase the process of decomposition, molasses, sugar, or manure can be added to the compost pile. The pile must be aerated by either turning the pile or by blowing air through it, which allows aerobic biodegradation to occur. If the oxygen level is not sufficient, the biodegradation will become anaerobic. Repugnant odors are released in the anaerobic process. The composting process is normally completed within a period of 6 to 13 weeks. At this point, the fraction of organic material which is readily biodegradable has been broken down, making the compost completely stabilized.[51] Stabilization refers to the cessation of chemical reactions and biological processes occurring within the compost. The remaining solids, called humus, can be added to soil as a conditioner. Because humus is not as rich in nitrogen, phosphorus, and potassium as fertilizers, it can only be used as a conditioner according to U.S. standards.[52] A more detailed discussion of the composting process is included in the section concerning backyard composting.

The cheapest and most technically simple form of municipally-operated composting is an outdoor windrow facility. In this facility, compostable waste is ground before it is piled in a row called a windrow. The dimensions of the windrow can vary, but the base needs to be twice as wide as the height to allow for

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[50] Rushbrook, Philip. Solid waste landfills in middle and lower-income countries. Pg 22.
[51] *Ibid.*, pg 595.
[52] Pavoni. Handbook of Solid Waste Disposal. Pg 32.

proper composting to take place.[53] The windrow is aerated once or twice a week. Windrows that are more frequently aerated have lower odor emissions.[54] Odor problems may still occur, but can be reduced by keeping a buffer zone between residences and the facility. An outdoor Municipal Solid Waste and Biosolid (sewage) composting facility in New York required a buffer of 500ft.[55] In some cases, decomposition of the waste is faster when sewage sludge is added to the compost pile. The sewage acts as food for the microbes that are responsible for the biodegradation process. The pathogenic bacteria present in sewage are not a health risk because they are forced to unsuccessfully compete with aerobic biodegrading bacteria. This process is known as biological self-purification.[56]

Concerning the equipment used at such a facility, a small dump truck would be required to collect and transport the pre- and post-composted waste. A shredding or turning device would be required to turn and aerate the windrows.

There are difficulties associated with municipally-run composting facilities other than possible odor emissions. Pre-composting separation of inorganic material from organic material requires participation of the local villagers to separate their wastes before collection (unless the municipality can afford to install a solid waste management facility that separates collected wastes). Without cooperation from the villagers, municipally-run composting would be an inefficient method of waste disposal. Regardless of this, a secondary disposal system, such as a landfill, for the non-compostable inorganics would be required. This would add to the total cost of the waste disposal system, which would be a hardship for the tambon. Also, there needs to be a desire for the end-product, humus, for composting to be profitable to the community. It is due to these reasons that large-scale municipally-run composting facilities have never been feasible in the United States.[57]

2.4.3.2 Recycling

Recycling of glass, plastics, metals, and paper products became increasingly popular in the U.S. during the 1990s. Packaging materials are mainly made from one of these types of materials. As previously mentioned, rural areas like Sang Khom are increasingly using man-made products such as glass, plastic, metal, and paper, to package their goods instead of natural products. For this reason, recycling has the ability to become an attractive method of managing municipal solid waste in rural Thailand. The components of a recycling system include collection, separation, reclamation and reprocessing, and finding markets for recycled products. Collection of recyclables can either be done at the curbside, at a central drop off location, or at a buy back facility. Table 3 illustrates the advantages and disadvantages of each collection scheme.

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[53] J. Glynn Henry. Environmental Science and Engineering. Pg 595.
[54] Science of composting. Pg 307.
[55] *Idem*
[56] Pavoni. Handbook of Solid Waste Disposal. Pg 31.
[57] *Ibid*, Pg 41.

Collection Method	Advantages	Disadvantages
Curbside	High participation	High investment
Drop-off center	Lower cost (no crew needed)	Low participation
Buy Back	Cash incentive encourages participation	Not comprehensive (not all items can be refunded)

Table 3 - Advantages/disadvantages of recyclable collection methods.[58]

Separation of wastes into recyclables and normal solid wastes can be done cheaply at the household or at a central waste management facility. Naturally, household separation would require a higher level of participation from the villagers. The third item, reclamation and the reprocessing system varies for each of the four recyclable items listed above, but is usually the most costly component. Finally, finding markets for recyclables is often times difficult to achieve. As we learned in Sang Khom, even if recycling is desired, it cannot be successful if there is no market for the recycled products.

The main benefit of recycling the four materials listed is decreasing the amount of waste that is disposed of in a landfill. Also, if the market is strong, profit can be made by the people participating in recycling. A major disadvantages of recycling is the initial increased cost of collection, sorting, shipping, and reprocessing of materials. If the market for recyclables is not strong, money can be lost. Also, the inability to establish a market for recycled products and the decreased quality of recycled products as compared to virgin goods makes recycling less desirable than other methods of waste disposal.

The cost of recycling is perhaps the biggest obstacle to overcome in order for a municipal recycling program to be successful. Currently, curbside collection and processing of recyclables is between 100 and 160 U.S. dollars per ton.[59] Curbside collection, shipping, and land filling of municipal solid waste is only 90 U.S. dollars per ton. As one can see, currently, it is cheaper to dispose of waste in a landfill. Establishing markets for recyclables may be unsuccessful if manufacturers are only willing to use virgin materials in the productions of goods. Sometimes the quality of the recycled product does not match the quality of a product made from virgin materials. This is particularly apparent in the recycling of paper products. During recycling, the cellulose fibers become shorter and weaker, causing the recycled paper product to have a shorter lifespan.

Though recycling seems to be economically undesirable, it has proven to be successful in parts of Thailand. According to the article "Empire Built From Junk" in the *Bangkok Post*,[60] Khun Somthai Wongcharoen owns a financially successful recycling plant that buys plastic, paper, metal, and glass, and then

[58] Dr. Vanee Komolprasent. Waste Recycling.
[59] J. Glynn Henry. Environmental Science and Engineering. Pg. 579.
[60] "Empire Built from Junk". Bangkok Post. January 2002.

sells them to available markets. He stated that 20 percent of the recycled material is sold to China, while the rest is sold on the domestic market. However, the profit margin is now only 10 percent, which is down from 100 to 200 percent in past years. Thailand's recent economic crash may be responsible for this loss of profit margin in the recyclables selling business.

If the tambon cannot profit from the collection and sale of recyclables, but still wishes to participate in recycling, it is possible for the local or national government to create incentives to promote recycling. The following options could increase incentives for local participation in recycling and increase the market for recycled goods:[61]

1. Encourage purchase of recycled goods through by imposing taxes on goods made entirely from virgin materials. This will make products with a recycled content be competitive.
2. Require markets to collect used bottles and recyclables
3. Reuse old appliances. Items such as radios and television sets could be collected and kept in a designated area to be picked up by other villagers for free.
4. Ban selected non-recyclable packaging materials.
5. The government could preferentially acquire products that contain recycled content.

The Global Cities Project entitled, "Building Sustainable Communities" produced a report in 1991 that mentioned that small municipalities are unable to attract buyers of recyclables. To gain access to a market, the community should try to pool its recyclables with larger areas. For example, 75 percent of the cities and towns in state of New Hampshire, U.S. cooperatively market their recyclables.[62]

If curbside collection is adopted, and villagers participate by separating their wastes at home, it will be necessary for the villagers to know what types of glass, plastics, metals, and papers can be recycled. The most common plastics recycled are Polyethylene Terephthalate (PETP) and High Density Polyethylene (HDPE). On plastic bottles, these two materials are marked by a triangle with a 1 or 2 located inside the triangle. Most types of green, clear, or amber colored glass can be recycled as well. Steel, aluminum, and tin are commonly recycled metals. Finally, most types of unglazed paper products can be recycled. Table 4, produced by the DCP in 1992, offers the average selling prices of unprocessed recyclables in Thailand.[63] This table can be used to compare the market values of one material compared to a different material.

[61] Building Sustainable Communities. Global Cities Project. 1991.
[62] *Idem.*
[63] This is outdated, and markets for recyclables may have changed dramatically in 10 years.

Material	Selling Price
	Baht/Kg
Plastic bottle	3.2-3.3
Broken glass bottle	0.3-0.3
Mekhong (white)	0.7-0.8
Beer (brown) bottle	0.1-0.2
Iron	1.5-1.6
Aluminum	14.7-17.7
Copper	39.7-49.7
Writing paper	3.2-3.3
Newspaper	1.3-1.8
Waste paper	0.8-1.1
Cardboard	1.2-1.4

Table 4 - Selling prices of unprocessed used goods[64]

2.4.3.3 Incineration

Incineration of municipal solid waste (MSW) is common in highly populated nations with limited space for landfills. The two most common types of incinerators are mass-burning incinerators and refuse-derived fuel incinerators. The difference between the two systems is that mass-burning incineration can handle MSW without the pretreatment or removal of non-combustibles that is necessary for the refuse-derived fuel incinerator. Separation, recycling, and disposal of incombustible metals, glasses, and other inert materials are essential to refuse-derived fuel incinerators. Refuse-derived fuel incinerators are generally smaller than mass-burning incinerators because the combustion is more efficient and fewer toxic emissions are released. The lack of motivation to separate waste is the reason why mass-burning incinerators are more common in the United States.[65] Most modern incinerators generate electricity, which is used to power the facility. The heat of combustion is used to boil water; super heated steam drives turbines that produce electricity.

If the incineration process were as simple as burning the garbage in a pit, the method would require virtually no funding for additional equipment. When air pollution controls becomes a concern, the required equipment makes the process extremely expensive. These pollution controls include:

1. The filtration of effluent gases (the smoke) to remove ash particles. Filtration is accomplished with the use of fine mesh bags that collect the particles. A second, more modern method to remove these particles from stack gases is the use of an Electrostatic Precipitator (ESP), which gives particles an electric charge and then collects them.[66]

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[64] Dr. Vanee Komolprasent. Waste Recycling
[65] Richard A. Denison. Recycling and Incineration. Pg. 60.
[66] Richard A. Denison Recycling and Incineration. Pg 205.

2. Scrubbing devices to remove toxic components such as hydrochloric acid and sulfur oxides. An acid-gas scrubber can be up to 99 percent efficient in the removal of these compounds.
3. NO_x controls. Aqueous ammonia, or urea, reacts to break down NO_x gases and can be injected into the flue gas stream.
4. An aeration system to carry extra oxygen to the burning pile. This decreases the formation of carbon monoxide gas. [67]

Because of the expense involved, high-income areas and large cities are the primary users of incinerators. Figure 11 - Initial investment vs. plant capacity and Figure 12 - Net annual operating costs vs. plant capacity. detail the costs compared to capacity. Figure 10 shows that the initial investment for a smaller incinerator is much greater for the amount of waste it handles, and larger incinerator is more cost efficient. Figure 11 shows that the operation and maintenance of a smaller incinerator is much less cost effective than a larger incinerator. These figures also show that a typical energy recovering incinerator will never be a profitable endeavor. For this reason, only large areas, with high waste production, use an incinerator for their primary means of waste disposal.

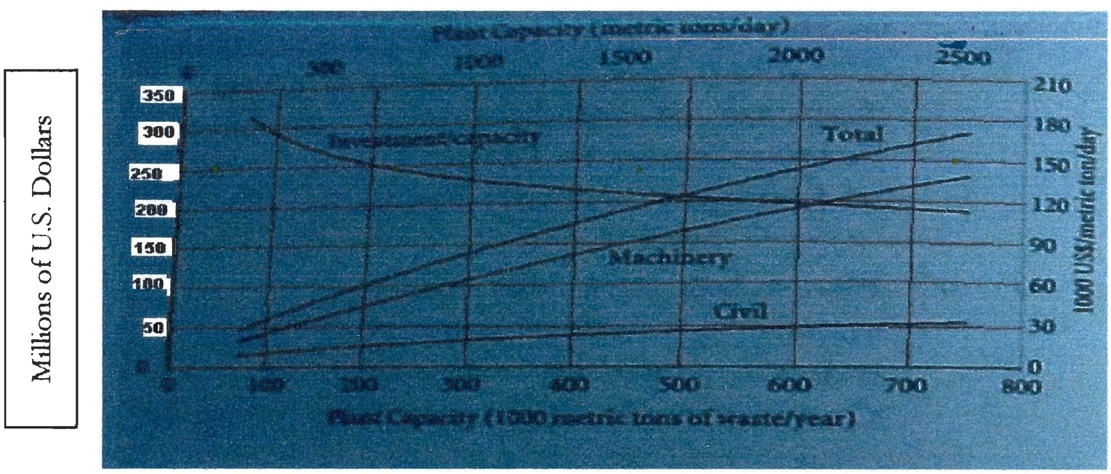

Figure 11 - Initial investment vs. plant capacity[68]

[67] *Idem.*

[68] World Bank. Municipal Solid Waste Incineration. Pg 24.

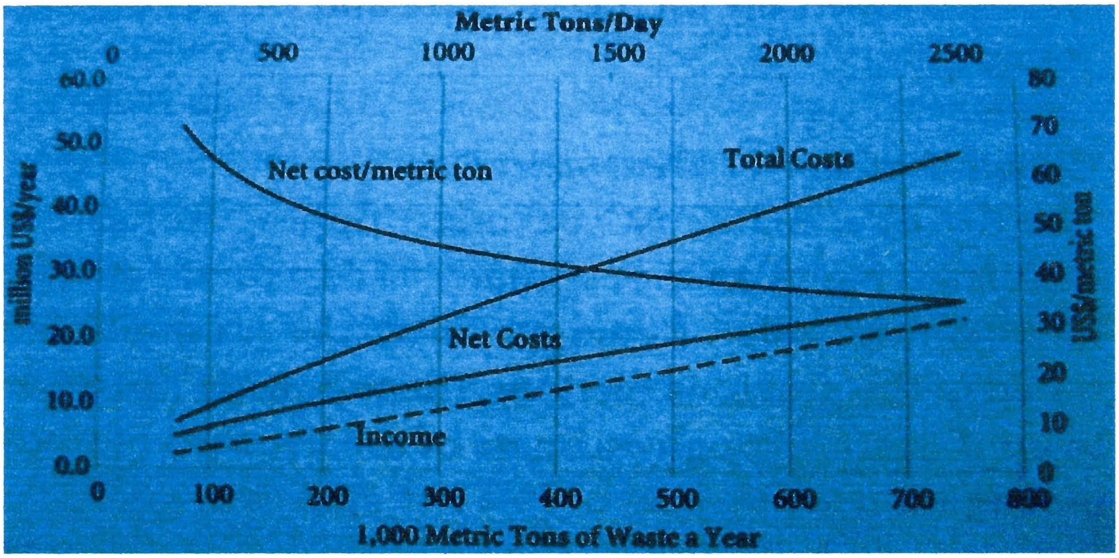

Figure 12 - Net annual operating costs vs. plant capacity.[69]

As further evidence of the high costs of constructing and maintaining an environmentally sound incinerator, the Millbury Wheelabrator, which has a 1,500 ton per day capacity, initially cost 130 million U.S. dollars in 1987. A proposed, but not implemented, incinerator in North Kingstown, RI, that was to have a 710 tons per day capacity would have cost over 160 million U.S. dollars in 1989. Although the plant capacities listed for the wheelabrator and the proposed Rhode Island incinerator are many time higher than the daily disposal rate of Sang Khom, according to the World Bank Technical Report entitled Municipal Solid Waste Incineration, a modern incinerator will only be economically feasible if there is a daily waste input of at least 240 metric tons per day. As stated previously, the tambon is only allotted less than 30,000 U.S. dollars per year to use for many aspects other than waste disposal. Despite the costs of the incinerator, many tambons would have to pool their waste to reach this high level of waste. Although it is highly unlikely, if the entire province of Udon Thani combined all of its waste, it is possible that this mark could be reached. If all of the tambons were able to come together and agree upon a new waste disposal system for the entire province, it would still be a challenge to acquire the necessary funds. If this system is proposed, the distance traveled by the waste disposal truck must be taken into account. According to the World Bank, the incinerator should be located within a one hour drive from the point of origin.[70]

Because incineration has the ability to reduce the volume of waste by 90 percent of the pre-combusted state and reduce its weight by 75 percent, it is understandable that densely populated areas, with limited free space, would prefer incineration to land filling.[71] Japan incinerates 68 percent of its MSW, while

[69] *Ibid.*, Pg. 27.
[70] World Bank. Municipal Solid Waste Incineration.
[71] *Idem.*

Switzerland and Denmark incinerate over 70 percent of their MSW. Incineration is less common in the U.S., where only 16 percent of MSW was incinerated in 1990.[72]

If a large-scale, environmentally-sound incinerator becomes feasible for the province of Udon Thani, the following recommendations have been made in the World Bank Technical Report:

1. A skilled independent consultant with experience in similar projects should be employed at the onset of planning.
2. The public should be informed of all phases of incineration planning and construction.
3. A landfill must be nearby to dispose of fly ash and residue from the combustion chamber.
4. The incinerator should be no less than 500 meters from residences.
5. A feasibility report should be produced that analyzes the composition of waste and the amount of waste to ensure proper combustion at the facility.
6. Money should be available for repairs and the purchasing of spare parts.

2.4.3.4 Land filling

Sanitary land filling is different from open-pit dumping because a sanitary landfill is engineered to prevent health and environmental hazards. The cost of constructing a sanitary landfill that meets the regulations of the U.S. EPA is extremely high. The managers of the Taunton Landfill and the Crapo Hill Landfill in Dartmouth, Massachusetts, were interviewed to determine construction and operational costs of large sanitary landfills. Both landfills dispose more than 300 metric tons per day. The managers of both sites mentioned that equipment required for construction cost over one million U.S. dollars. The actual construction of the site was well over 10 million U.S. dollars.[73]

There are levels of environmental and health protection below the U.S. standard that will decrease the costs, but these alterations will also decrease the effectiveness of the sanitation precautions. The lowest form of land filling is called open dumping. This is the type of land filling that is used in the tambon of Sang Khom. One level above open dumping is called controlled dumping. This method of land filling is superior to that of open dumping because waste in the landfill is covered daily with soil. The third level of land filling is called engineered land filling. In addition to covering the waste daily, this method requires a system to control the removal of leachate, spreading and compacting waste in layers prior to covering the waste, and an improvement in the isolation of the waste from nearby water supplies. Finally, in addition to the systems utilized in engineered land filling, the method called sanitary land filling uses technically complex gas venting systems and a system for leachate collection and treatment.[74] This section discusses protection schemes that exist at the level of engineered and sanitary landfill.

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[72] Henry J. Glynn. Environmental Science and Engineering. Pg. 590.
[73] The manager of the Taunton Landfill is Denis Hammon and the manager of the Crapo Hill Landfill is Hank Van Laar Hoven. Both of these men were interviewed by phone.
[74] Rushbrook, Philip. Solid waste landfills in middle and lower-income countries.

There are three major filling techniques in the construction of a landfill: area method, trench method, and ramp method.[75] In the area method, the waste is dumped on undisturbed ground. For the trench method, a long and narrow trench is excavated for the disposal of waste. This method is suitable when the groundwater level is relatively deep. The ramp method is a hybrid of the previous two methods. Figure 13 illustrates the trench and ramp land filling methods.

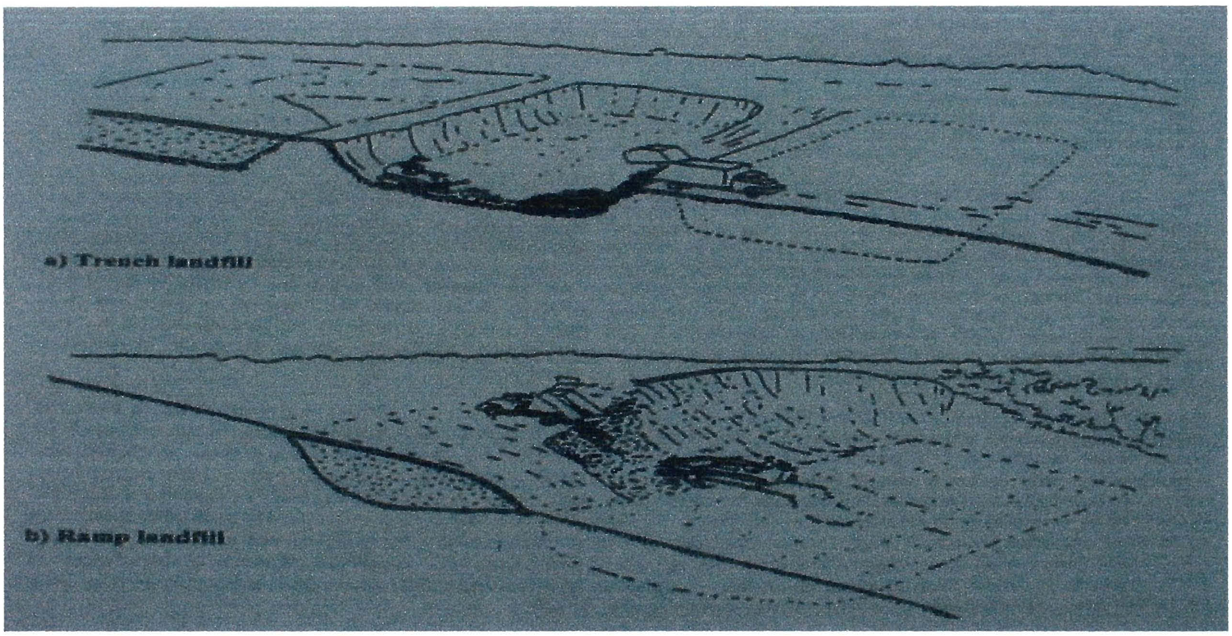

Figure 13 - Trench and ramp landfill filling schemes[76]

The major environmental concern with landfills is the possibility of leachate migration to local water. If the groundwater table is close to the surface and is used as a drinking water source, extra care must be taken in order to prevent contaminated water from reaching the aquifer. At least three meters of non-cracked and unsaturated low permeability earth (i.e. clay silt) must be kept between the groundwater table and the landfill waste.[77] Low permeability is defined as soil that allows percolation of liquids at velocities no higher than 10^{-7}m/s. Some sources have even indicated that at least five meters of this geological barrier, such as the clay silt, should be kept between the landfill and the ground water.[78] The geological barrier should also have a high natural retention capacity for hazardous substances and a thin surface coverage, less than two meters between the surface of the landfill and the top of the geological barrier.[79] Figure 14 illustrates typical earth strata.

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[75] Pavoni. Handbook of Solid Waste Disposal. Pgs 173-176.
[76] World Bank. Solid Waste Landfills in Middle- and Lower-Income Countries. Pg.76
[77] *Ibid* pg.86.
[78] http://www.dmr.go.th/Project/Thai_Ger/TP2thaiD.htm
[79] *Ibid.*

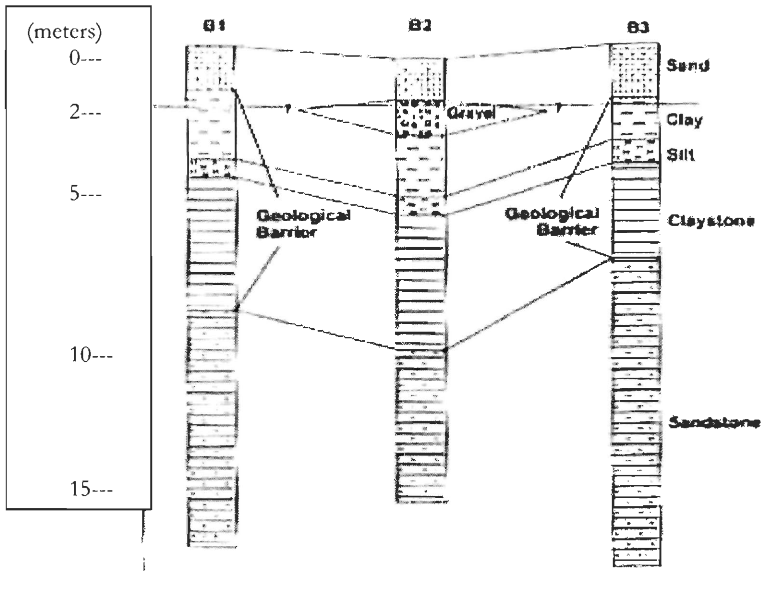

Figure 14 - Diagram of typical earth strata[80]

The top one meter is composed of loose sand. The geohydrological boundary layer that consists of clay, silts, and clay stone extends to approximately eight meters deep.

A man-made barrier, such as a plastic liner, can also be used to decrease the risk of leachate reaching groundwater. This type of liner needs to be stable for at least 30 years to prevent contamination from any hazardous leachate.[81] This length of time is given because the typical lifespan of a sanitary landfill should be close to 30 years.[82] To prevent punctures of this liner, at least six inches of soil should be compacted over the liner before heavy equipment traverses the base. The discharge of leachate can be delayed for many years if the soil cover of a landfill has a high absorption rate. When leachate reaches the basal layer, it is possible to drain it from the landfill. In order to drain any leachate, a layer of granular material, or drainage blanket, is placed over the basal liner, and a network of perforated PVC piping is put into this material. These pipes are generally at least six inches in diameter and are separated by 30-50 meters. The drainage blanket must have a declining slope in order to allow the leachate to flow towards the drainage system. The drained leachate then needs to be managed in some fashion. Figure 15 shows how sloping the base of landfill can allow for leachate to drain out of a landfill. A dike can also be created at the lowest point in the drainage blanket field with the collection pipes going through the dike, causing leachate to flow out of the landfill. It may be treated or left to evaporate in this isolated collection area.

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[80] Matthias Dorn. New Methods for Searching for Waste disposal sites in the Chiang Mai-Lamphun basin, Northern Thailand. Pg 514.
[81] *Ibid.*, pg 508.
[82] *Idem.*

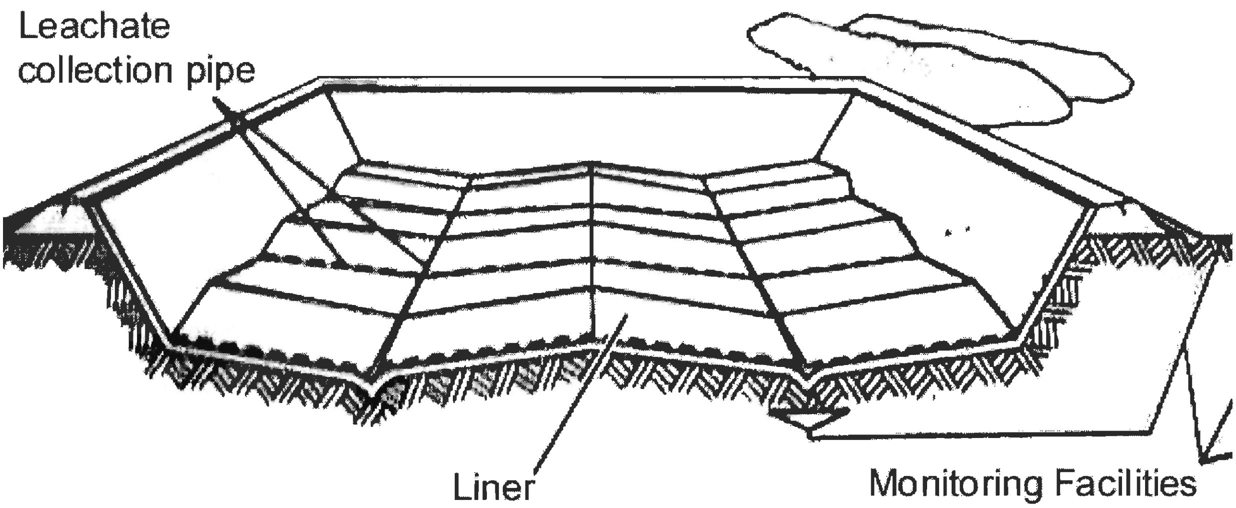

Figure 15 - Schematic for a leachate drainage and collection system[83]

Groundwater contamination by leachate is not a problem in areas where the rate of evaporation is higher than the rate of rainfall because no water is able to build up within the landfill. Recycling leachate through a landfill can actually increase the rate of biodegradation, which in turn causes the landfill to settle faster and produce more methane. This methane that is created can be collected and harnessed to produce energy in many forms, such as electricity.

As previously mentioned, a landfill should be covered daily, in order to reduce the attraction of birds, rodents, and flies to the garbage. Only the exposed waste is covered by a layer of dirt at the end of the day as opposed to the entire site being covered. This daily cover helps to reduce the scattering of waste caused by wind and hinders the flow of rainwater to the underlying waste. The cover layer should be between 6 and 12 inches to be effective and can be composed of sand, silt, or clay.[84] This will add to the stability of the cover, enabling trucks to drive over it, while preventing water from draining into the underneath waste. Table 5 illustrates the effectiveness of various materials that can be used as a daily cover for waste.

Biodegradation of organic waste yields a mixture of methane and carbon dioxide gases. The methane from this waste can be collected and used as a minor power source. Dr. Lingappa, a professor of Biology at the College of the Holy Cross, said in an interview, that the composition of the escaping gases is time dependant. During the first few years of a landfills existence, aerobic bacteria mainly produce carbon dioxide gas. This carbon dioxide production has a possibly adverse effect. CO_2 can react with water in the leachate to form carbonic acid. If the leachate migrates to the aquifer, the pH of the groundwater will drop below normal levels.

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[83] Pavoni. Handbook of Solid Waste Disposal. pg 262.
[84] Philip Rushbrook.

Function	Cover Material					
	Yard waste mulch	Yard waste compost	MSW compost	Geo-synthetic clay liner	Typical native soil	Clay-silt sand
:s and prevention of flying debris	G-E	G-E	G	E	E	E
on of rodents from tunneling	P	P	P	G-E	P	F-G
flies from emerging	F	F-G	F	E	G	P
ıg surface water entry into landfill	P	G-E	F-G	E	F-G	P
ıg landfill gas venting through cover	P	P	P	F-G	P	P

Table 5 - Cover material vs. function.[85]

In later years, when the oxygen levels inside the landfill have been reduced, anaerobic bacteria become more prevalent and produce methane. Figure 16 illustrates the five phases of landfill gas production.

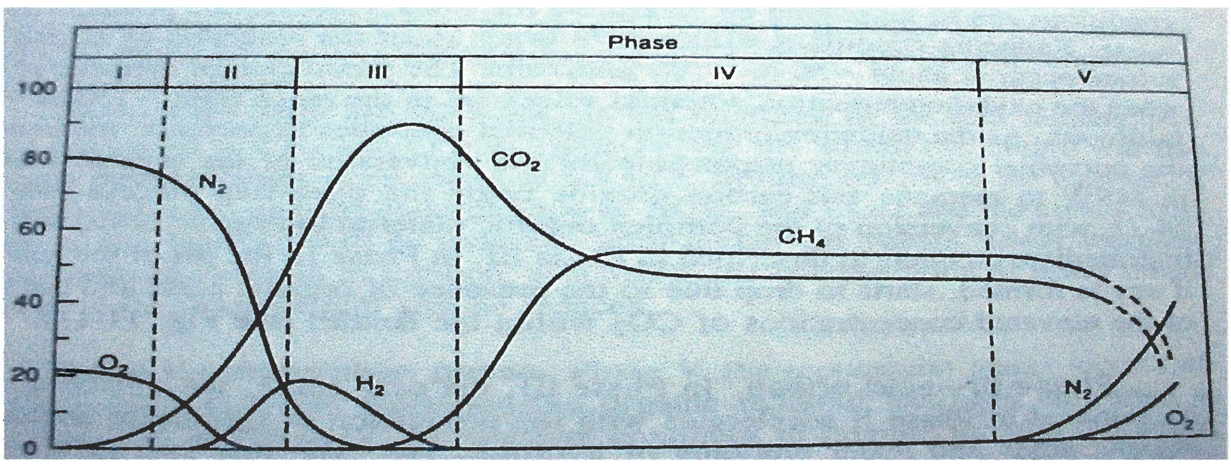

Figure 16 - Time dependant concentrations of landfill gases[86]

The five phases of landfill gas production are known as the initial adjustment phase, the transition phase, the acid phase, the methane formation phase, and the maturation phase. The methane formation phase does not begin until after one full year of waste burial has elapsed. During this phase, methane concentrations build to over 50 percent of the total gas concentration. At this time, the ability to convert methane to energy is great.

Gases that build-up within large landfills should be allowed to vent in order to prevent the build-up of methane. If methane is allowed to build up over a long period of time, it can lead to a disastrous explosion. In fact, methane is explosive at concentrations as low as 5-15 percent by volume.[87] Figure 17, Figure 18, and Figure 19 all illustrate methods for gas ventilation.

[85] Dr. Frank Keith, P.E. and Dr. W. Klausmeier. Course Notes for a Workshop on Solid Waste Management.
[86] Sanitary landfill pg.III-3
[87] *Ibid.*, Pg III-4.

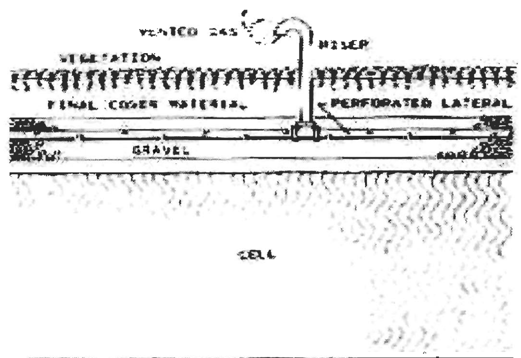

Figure 17 - Venting gas via perforated pipes[88]

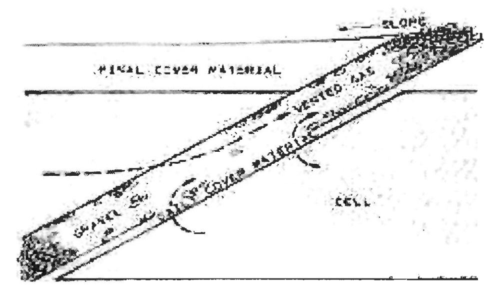

Figure 18 - Alternate gas venting schematic[89]

[88] *Ibid.*, Pg. V-7.
[89] *Idem.*

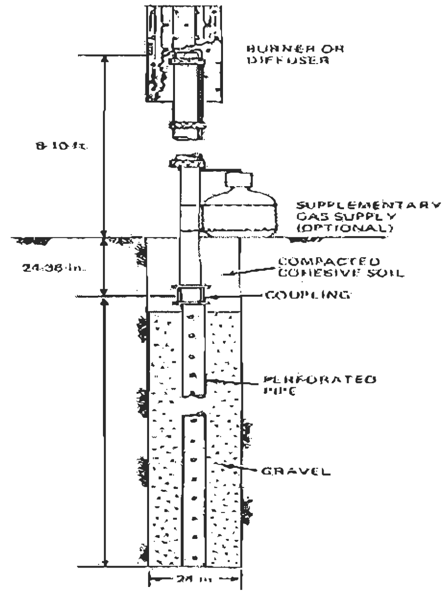

Figure 19 - Gas venting and destruction[90]

Because methane production increases with time, only old landfills are viable sources of energy that utilize methane. For example, a 17 acre landfill in Burlington, Vermont, which was constructed for a cost of $800,000, holds 850,000 tons of refuse and uses two generators to produce an average of 520 kilowatts of energy per day. Eighteen vertical extraction wells collect the gas at a rate of 320 cubic feet per minute.[91] A project in Missouri cost $175,000 to setup a 3,600 ft pipeline that vented methane from the nearby landfill to a local high school's basement boilers.[92] According to the U.S. EPA website on gas-to-energy promotion, 1 million tons of waste can generate up to 300 cubic feet per minute of gas that can generate up to 7,000,000 kilowatt hours. This is enough to power 700 homes for a year.[93]

The equipment needed for a small sanitary landfill may be limited to only two devices: a dump truck, and a bulldozer. The bulldozer would be needed to excavate the earth, move the garbage, and compact it. The dump truck would be needed to transport all of the waste efficiently. Table 6 illustrates the functions of typical landfill equipment. If engineered properly, a sanitary landfill can be environmentally friendly. Aesthetic appeal may be its only drawback if proper care is used to control disease vectors, leachate contamination of groundwater, and methane gas emissions.

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[90] Pavoni. Handbook of Solid Waste Disposal. Pg 188
[91] Cohen, Shelly. Small Landfills, Big Benefits. Pg. 230.
[92] http://www.epa.gov/lmop
[93] *Ibid.*

Type	Solid Waste		Soil Cover			Site Prep. and Maintenance
	Spreading	Compacting	Excavating	Covering	Hauling	
Crawler dozer	E	G	E	G	NA	G
Crawler loader	G	G	E	E	F	G
Landfill compactor	G	E	P	F	NA	P
Rubber-tired dozer	G	G	F	G	NA	F
Rubber-tired loader	F	G	F	G	G	F
Scraper	NA	NA	G	G	E	F
Dragline	NA	NA	E	F	NA	F
Grader	NA	NA	G	NA	NA	G

Note: E=excellent, G=good, F=fair, P=poor, NA=not applicable.

Table 6 - Typical landfill equipment and their functions[94]

2.4.4 Land filling in Thailand

Through interviews with officials in Prachuap and Hua Hin, our team learned that the government does sponsor the development of large-scale sanitary landfills. During a visit to Prachuap, we interviewed the Lord Mayor of Pranburi, Pornthep Visutvatanasak, concerning a proposed large-scale sanitary landfill to be constructed in the next few years. Pranburi is considered a municipality in Thailand as opposed to a tambon. A municipality is labeled as a city in the United States, while a tambon could be labeled as town in the U.S.

Khun Pornthep first gave a brief background of Pranburi's current waste disposal system. He stated that their waste disposal site is only 1 hector in area, which he felt was too small to support the waste generated in the municipality. The waste management system is funded through local taxes, where 10 baht per month per family is collected. Because this does not cover all expenditures required for waste collection and disposal, the government of Pranburi was forced to subsidize the system with other types of taxes. Even this measure could not prevent Pranburi from facing a deficit due to the high cost of waste disposal. Other municipalities and tambons in the area have been facing the same problem according to Khun Pornthep. Officials from these municipalities and tambons expressed their concerns that their solid waste disposal systems would begin to pose and environmental and health problem in the near future. Four municipalities and 16 tambons in Prachuap decided to discuss these problems and developed a proposal for the construction of a large scale solid waste management system. Because the area involved is so large and has such a great population, Prachuap was successful in acquiring funds from the National Environmental Fund (NEF). The NEF is sponsored by the Ministry of Science, Technology, and Environment (MOSTE). Prachuap received a 4 million baht (91,000 U.S. dollars) budget to conduct a one year feasibility study and to

[94] Sanitary landfill. Pg. VI-2.

design a sanitary landfill for the area. Approximately 550 million baht (12.5 million U.S. dollars) was allotted for the construction of the facilities by the financial supporters.

Khun Pornthep offered details of the ongoing feasibility study which is being managed by the Sena Development Company., LTD. [95] The proposed landfill will support 150,000 people in 4 municipalities and 16 tambons. The transfer stations will be positioned so that collection vehicles do not travel more that 30 km from point of pickup to point of drop off. At these transfer stations, it is planned that the solid waste will be separated into recyclable waste, compostable waste, and wastes that must be disposed of in the sanitary landfill. The Lord Mayor indicated that only 18% of its waste stream must be disposed of in a sanitary landfill, while the remaining 82% can be either recycled or composted.

The landfill is expected to last 20 years, which is a standard maximum lifetime for a sanitary landfill in Thailand.[96] The expected cost of disposal is 200-300 baht per ton. The site will collect and use landfill gas for electricity generation.

The government of Prachuap is considering the separation and selling of recyclables at the previously mentioned transfer stations. Currently, scavengers receive 1 baht per glass bottle, which is much higher than the price received in Sang Khom. The reasons for this difference are unknown. Our hypothesis is that the larger size of Pranburi allows for easier access to a recyclable buying market. In fact, a retired bank manager now owns a business in the area that buys and sells recyclables.

Our team also visited the current operating sanitary landfill in Hua Hin. This landfill supports 40,000 people, who live in an 86 square km area. Hua Hin also only collects 10 baht per family per month for curbside collection of solid waste. Approximately 700,000 baht (16,000 U.S. dollars) per year is collected from the waste disposal fees. The officials at Hua Hin claimed that they are not receiving any central government subsidy for the maintenance and operation of the current site. The officials also stated that the cost of disposal is about 270 baht (6.1 U.S. dollars) per ton. The construction of the current site was paid for by the Ministry of Science, Technology, and Education. This site was constructed 10 years ago at the price of 70 million baht (1.6 million U.S. dollars).

Details of the landfill were discussed during a tour of the waste disposal site. The site manages all of Hua Hin's waste, and recyclable and compostable materials are not removed before disposal. The land filling area is 14.4 hectors and is composed of four dumping zones. Each zone is separated by an earthen dike which is also used as an access road for dump trucks. Each zone contains four layers of cells, each cell being two meters thick.

Two of the four zones utilize a 1 mm HDPE basal liner to prevent leachate migration. The leachate is drained by 8" perforated PVC piping that is surrounded by a layer of gravel. Above the gravel and the exposed HDPE liner, 30 cm of native soil was compacted to decrease the possibility of damage to the liner

[95] Sena Development Co., LTD. Phone number: 662-9544615-8.
[96] This figure was offered by the Lord Mayor of Pranburi, Pornthep Visutvatanasak.

due to heavy loads. Once gathered, the leachate drains to digestion pools; three pools of 20 x 20 meters and two pools of 20 x 60 meters are used to treat the leachate. It was mentioned by the tour guides that the incoming leachate has a biological oxygen demand of 400, while the outgoing water can support fish and other aquatic organisms due to a low biological oxygen demand of 3.[97] To manage the runoff of rain from the site, a storm drain that surrounds the entire landfill was installed during construction.

The disposed waste is covered daily with 15 cm of native soil. When a cell is filled completely, it is covered with 30 cm of native soil. When a zone is to be closed, a final cap of 60 cm of native soil is compacted on top. The site has 1 dozer tractor to excavate earth, but our tour guide mentioned that one dozer is not enough. He would prefer to have a spare dozer in case the current dozer breaks down.

The waste disposal site also has a gas ventilation system. Large perforated concrete pipes were placed into the landfill to allow landfill gases to escape. These gases are not collected, but allowed to enter the open air. Our tour guide mentioned that the site currently employs seven people. Three drive dump trucks and the site's one dozer-tractor. One person is the weigh station attendant; there is one guard, one manager and one spare driver.

Our team's impression of this sanitary landfill was a positive one. The site seemed to be run in an efficient manner and the site's design indicated that the designers of the site adequately considered environmental and health issues. Our only concern was the excess of light plastic wastes on top of the earth covered cells. We also hoped to see some sort of recycling or composting system in Hua Hin. Our guide mentioned that Hua Hin's local government was considering the installation of a recycling and a composting facility at the landfill site, which could be implemented within two or three years if approved.

2.4.5 Waste reduction options

Personal waste reduction, backyard composting, and family-run methane generators are three options that would decrease the amount of waste that is collected and disposed of by an area's central waste management system. A community can be encouraged and taught how to reduce the amount of waste produced by each person. For an area that wishes to reduce its waste production, the governments could impose volume-based fees for general waste disposal. As evidence of effectiveness, the city of Perkasie, Pennsylvania, saw a 28.7 percent decrease of the weight of general waste when they started to charge a fee for each waste disposal bin collected.[98]

Backyard composting is considered to a form of waste reduction that involves minimal costs, but requires local participation in order to be effective. With minimal equipment, a community can dramatically reduce the amount of waste disposed, while generating a valuable product. As mentioned previously, this product, called humus, can be used as a natural soil conditioner. Organic farmers can use humus as opposed

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[97] The units used for Biological Oxygen Demand (BOD) are unknown.
[98] "Building Sustainable Communities" Global Cities Project. 1991.

to chemical fertilizers to ensure the purity of their produce. From our interview with the local Tambon Council in Sang Khom, we have learned that farmers can utilize the humus to their advantage.

The process of composting occurs when appropriate mixtures of water, oxygen, heat, "green materials", and "brown materials" are available to aerobically decomposing microorganisms. "Green materials" are nitrogen rich items such as fresh grass, food scraps, and manure. "Brown materials" are carbon rich items such as dry leaves, and woody stems. By turning the pile at least every two days, oxygen levels are kept high enough to support the anaerobic microorganisms. To keep water levels high enough for the microorganisms, it is suggested that the pile be placed under a tree or covered in a hotter area. The time required to complete composting is variable and can range from 1 month to 2 years.[99] Backyard composting methodologies can be found in the book, Backyard composting printed by the Harmonius press in Ojai, California, 1992.

Backyard composting projects have been successful in Thailand. The example used is the Loei River Conservation project sponsored by the Thailand's General Environmental Fund / Small Grants Programme (GEF / SGP) under the United Nations Development Programme (UNDP). Khun Poonsin, the national coordinator of the GEF /SGP discussed this successful project during an interview. The project was based in the Erawan Sub-District of the Loei province. The main activity of the project was to develop composting projects at five schools in five neighboring villages. The goals of this project were:

1. Encourage the students to promote backyard composting at their homes.
2. Reduce the amount of waste disposed in landfills due to composting.
3. Reduce the use of synthetic chemical fertilizer used in agriculture to save money and to promote health of the consumers.

The family-run methane generator system is similar to backyard composting because the same types of yard waste and food waste can be decomposed. The difference is that the process must be anaerobic to produce methane. To do this, the pile must be completely enclosed to prevent oxygen from promoting the growth of aerobic bacteria. Dr. Lingappa of Holy Cross College began research in this field in the 1970s and has patented a family size methane generator. In an interview, he stated that families in India successfully use this simple technology to provide electricity to their home. Dr. Lingappa mentioned that cow manure was the best waste type to use in this system in order to quickly generate methane. He said that if yard wastes were properly mixed with farm animal wastes, adequate methane would be produced to create electricity. He then suggested that this waste disposal system would be ideal for small farming families.

2.5 Possible Sources of Funding

Creating an environmentally sound waste disposal system is a large investment and can cost upwards of a million dollars. It is known that the purchasing of construction equipment to redesign or relocate the dumping site is well beyond the tambon's available budget. One goal of this project is to seek funds from

[99] Backyard Composting. Multiple pages.

charities, organizations, or from a department of the government. Contact information for appropriate governmental organizations are offered here in the event that funding is required for a similar project.

1) Ministry of Science, Technology, and Environment: http://www.moste.go.th/eng/main.html
   a) DEQP: http://www.deqp.go.th
      email: info@deqp.go.th
   b) PCD: http://www.pcd.go.th
      The Director General is Mr. Sirithan Pairoj-Boon. Email: Sirithan.P@pcd.go.th
      The Deputy Director General is Ms. Nisakorn Kositratna. Email: Nisakorn.K.pcd.go.th
   c) OEPP: http://www.oepp.go.th/eng/about_oepp.html
      The Secretary General is Dr. Saksit Tridech. Email: saksit@oepp.go.th
      The Deputy Secretary-Generals are Ms Chirawan Pipitphoka. Email: chirawan@oepp.go.th
      Dr. Wanee Samphantharak. Email: wane@oepp.go.th
      Mr. Apichai Chvajarernpun. Email: apichai@oepp.go.th
2) Education for Development Foundation:
      Senator Somkid Sreesangkom
      General Manager Sakon Sookkho. Email: admin@edfthai.org

Non-governmental organizations that are possible sources of funding are:

1) The United Nations Development Programme in Thailand. This organization has been active since 1955 and will intervene with water resource management, pollution control, mitigation of natural disasters, renewable energy development, and biological resource rehabilitation. The website http://www.undp.org offered the following contact email. Registry.th@undp.org
2) The Global Environmental Fund/Small Grants Programme in Thailand. Many nations have similar GEF organizations that provide funds so that the country can carry out activities to protect the local and global environment. Our contact is the National Coordinator Khun Poonsin Sreesangkom. Email address: Poonsin.sreesangkom@undp.org. The GEF/ Small grants programme also exists as an international organization. "By providing financial and technical support to projects in developing countries that conserve and restore the natural world while enhancing well-being and livelihoods, SGP demonstrates that community action can maintain the fine balance between human needs and environmental imperatives."[100] The international SGP currently has 2300 projects in 60 countries. The SGP will provide up to 50,000 U.S. dollars per grant to NGOs and CBOs (non-governmental organizations and community based organizations).

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[100] Global Environmental Fund/Small Grants Programme brochure

3) The International monetary fund lends money to developing nations and receives its funding from the UNDP, EU (European Union), and local charities. The official website is http://www.imf.org
4) The British Community in Thailand Foundation (BCTFN). This organization gives grants of up to 500,000 Baht (11,400 U.S. dollars) to developmental projects such as this. The email contact is bctfn@loxinfo.co.th.

3. METHODOLOGY

This project is designed to assist the tambon of Sang Khom, in the province of Udon Thani, Thailand, by assessing the feasibility of implementing a more sanitary solid waste disposal system. The project team has assessed the current waste disposal system and has assessed the feasibility of alternate systems by evaluating the tambon's available budget, analyzing the social and environmental implications of each method, and determining if the required technology and education will be available to implement this method. After the completion of this study, our team prepared a proposal for improving the tambon's waste disposal system. This proposal was delivered to our sponsor, the Tambon Council, and organizations that may assist the tambon of Sang Khom in the project. The primary objectives of our project were:

1. To evaluate the current method of waste disposal
2. To assess the feasibility of alternative systems
3. To develop a proposal to improve the waste disposal system

The sections that follow provide details of the methods adopted to fulfill these objectives. Section 3.1 defines the domain of study, the geographic area of study, and all uncommon or technical terms used in this methodology.

Section 3.2 contains the methods used for the completion of the evaluation of the current waste disposal system. This section is divided into three segments. The first segment details the methods we used to characterize the physical aspects of Sang Khom's waste disposal system. The next segment describes the methods we used to assess the complaints and opinions of those people who use, operate, manage, or are connected in some way with the current waste disposal system. The third segment details how we assessed the health and environmental hazards of the current system.

Section 3.3 contains the methodology used for the completion of the assessment of the feasibility of alternative systems. This section is divided in six segments. The first four segments discuss the methods used to assess the technical feasibility of constructing the facilities used for environmentally sound incineration, sanitary land filling, windrow composting, and municipally-run recycling. The next segment is devoted to the methods used in assessing the desirability and social feasibility of the potential alternative methods. The final segment details how we evaluated the possibility of waste reduction within the tambon.

Section 3.4 contains the methodology used to complete the proposal for the improvement of the waste disposal system. This section also describes how we searched for agencies that could offer funding or equipment for this project.

Section 3.5 contains the general interviewing methods used throughout the course of this project.

3.1 Domain of Inquiry, Geographical Study Area, and Definitions

We limited our inquiry to the solid waste disposal methods that are currently utilized in the tambon of Sang Khom and to the systems of environmentally sound incineration, sanitary land filling, and composting. Recycling was a limited part of our inquiry. We investigated the possibility of having the villagers separate their wastes to have recyclables collected and shipped to the nearest recycling facility. We searched for an existing facility because the construction of a recycling facility would be well outside the annual budget of 1.2 million Baht (27,000 U.S. dollars), which is a combination of local taxes and national funding. This figure for the annual budget was obtained through our interview with the Tambon Council. Our team also investigated personal waste reduction options, such as backyard composting and waste-derived methane production.

Our team inquired only about rubbish and garbage out of the many types of solid waste. Hazardous waste and water waste (sewage) are not within our domain of inquiry. Our area of inquiry is the tambon of Sang Khom, in the province of Udon Thani, Thailand. See Section 2.1 The Kingdom of Thailand and the Tambon of Sang Khom for a basic map of the area.

In order to properly discuss the technical aspects of waste disposal, the following terms need to be defined: rubbish, garbage, waste stream, putrescible, social feasibility, evaporespiration, and geohydrological study. Rubbish is defined as combustible or noncombustible solid waste material from households, stores, offices and institutions.[101] Rubbish includes paper products, wood, plastics, cloth, leather, rubber, yard trimmings, metals, dirt, stone, ceramics, and glass. Garbage is defined as the animal and vegetable waste resulting from handling, preparing, cooking, and serving of goods and originates primarily in household kitchens, stores, markets, restaurants, and hotels.[102] Waste stream refers to the waste that is produced by a community in a defined location. Putrescible is an adjective describing solid waste that consist of biodegradable plant material. Social feasibility refers to our examination of the likelihood that our project will or will not conflict with the lifestyle of the people connected to the waste disposal in Sang Khom. The most important group of people to consider is the tambon villagers. Evaporespiration, or evapotranspiration, is the combined loss of water from evaporation and the consumption of water by vegetation at the landfill site.[103] Geohydrology is the study of soil composition at various strata and the study of underlying aquifers.

3.2 Methods for the Evaluation of the Current Waste Disposal System

In this section, we discuss the methods used to evaluate the current waste disposal system in the tambon of Sang Khom. A physical description of the current method has enabled us to determine the health

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[101] American Public Works Association. <u>Solid Waste Collection Practice.</u> Pg 16.
[102] *Ibid.*, pg. 15.
[103] Edward A. McBean. <u>Solid Waste Landfill Engineering and Design.</u> Pg.133.

and environmental problems associated with each method. We also assessed the problems the villagers, doctors, tambon officials, and our sponsor have with the current system.

3.2.1 Methods used to obtain a physical description of the current system

We obtained a complete physical description of the tambon's current waste disposal system in order to determine what health and environmental problems lie within the system. This section describes what types of information we sought and how we went about obtaining it.

We first physically observed the tambon's waste disposal system. We visited the current dumping and burning site to take photos and noted the engineering and design considerations of the site. We visited the site prior to any of our interviews so we could have an understanding of what was being spoken of. During our first day at the village, we were driven to the waste disposal site to observe. We sought to determine if any leachate management controls were in place and whether the site's waste was completely exposed or was covered with dirt. Notes were taken as to what we viewed and what our opinions were concerning the site. We then drove to a town building, where local officials would most likely meet. The waste disposal truck was parked beside the building, under a roof. We took photographs of the collection truck and the rubber waste bins that were located near by. We the measured the volume of the bed of the truck with a tape measurer and recorded it into our notes. The next day, Khun Poonsin drove us to the local hospital to observe the controlled incineration of bio-hazardous wastes. We asked the operators about existing emission controls in the unit and how the incineration residue is disposed.

Secondly, we interviewed Khun Somchai Moonjak, who has been part of the tambon's solid waste collection crew for the past six years. We interviewed him at his home on a Sunday afternoon. We asked him questions through Khun Poonsin, who translated for us. Khun Somchai would then reply to Khun Poonsin, who translated his answer back to us. Khun Somchai is currently classified as a driver of the collection vehicle, but works with two other workers to collect the waste. See Appendix G.1 Interview with tambon waste disposal manager for draft of interview form. The following information was sought during the interview:

1. A description of the current garbage collection system, including frequency of pickup, collection crew size and functions, and cost of equipment.
2. His opinion of the likelihood of disease vectors accessing the waste bins.
3. Information on the reliability of waste pickup to determine the efficiency of current collection system.
4. Information about the composition of the waste stream and the tambon's daily generation of waste.
5. A description of the current open dumping of solid waste. We sought information concerning the site's engineering and design. Khun Somchai offered his opinions of the ineffectiveness of the leachate collection system and his concerns with disease vector access to the pit.
6. His opinions and description of the current incineration of solid waste at the dumping site.

The final task in this section was to determine the composition of the tambon's waste stream. We sought to determine the percentage of biodegradable waste, water, and the other components listed in Table 2. Interviews with a few selected market owners and families helped us determine what types of wastes the people of the tambon create. In the evenings, we walked with Khun Poonsin around the village and spoke with villagers who were outside. Meetings were brief and informal, and were mainly used to become more oriented with the villagers. The interview with the garbage manager gave us the needed information to determine the composition of the waste stream.

3.2.2 Methods used to identify local perceptions of the current waste disposal system

To determine the basis for this project, we sought opinions and regulations from the tambon's villagers, Senator Somkid Sreesangkom, local and national laws, the Tambon Council, and Khun Poonsin Sreesangkom, who is a well respected local, the treasurer of the Education Development Foundation, and a National Coordinator for the GEF/Small Grants Programme of Thailand.

Prior to visiting the tambon, we met with Senator Somkid Sreesangkom to find out his underlying reasons for asking us to consider proposing a new system of waste disposal in the tambon. We met with Senator Somkid in the Parliament building of Thailand. First, we were given a tour of Parliament by Senator Somkid, then we interviewed him in the lobby. We asked him if the complaints of odor were the only issues that motivated him to seek improvements in the current system. We asked for his overall opinion about the current system and what he would like to see changed. We also determined the best time to visit the tambon of Sang Khom and what would be done while visiting the villages. After our meeting, Senator Somkid invited our group to eat lunch with him.

During our first visit to the tambon, we interviewed the Tambon Council, Poonsin Sreesangkom, and local villagers to determine their perceptions of the current waste disposal problems. These interviews were conducted in order to understand the current waste disposal system's problems as perceived by these people. Detailed forms of these interviews are found in Appendix G-Sample Interview Forms. In our interview with Tambon Council, we sought the following information:

1. Their concerns with the current waste disposal system and their opinions of how it could be improved.
2. Demographics of the tambon.
3. Their concerns with air pollution and water pollution as a result of environmentally unsound waste disposal system.
4. Their opinion of the reliability of the waste collection.
5. The tambon's waste generation rate.
6. The location of maps (standard and topographical) that would show the location of the open dumping site, the 12 villages, wetland areas, and water ways.
7. The tambon's yearly budget.
8. The price and source of land used for the current dumping site.
9. Equipment costs for collection and maintenance of the dumping site.

10. Their concern with animals spreading disease from the improperly managed dumping site to nearby villages.
11. Weather statistics of the tambon.
12. Their opinions of alternate waste disposal methods.
13. Their opinions as to how the community could be educated and motivated to participate in recycling and backyard composting.

Our interview with Khun Poonsin sought the same information as listed above as well as the following information:

1. How to contact waste disposal experts that could be hired to work with the Tambon Council in improving their waste disposal system.
2. His efforts to improve solid waste disposal in the tambon.
3. His expectations of this project.
4. His knowledge of existing recycling facilities near Sang Khom.
5. His knowledge of the use of environmentally sound incinerators in Bangkok.

We also interviewed a few villagers from Ban Khok who live less than 1.6 kilometers away from thecurrent waste disposal site (This is the closest residential area to the dumping site). Ban Khok is not part of Sang Khom, but is part of the tambon of Phen. Khun Poonsin selected several villagers with whom we discussed their concerns about the nearby dumping site. We interviewed the villagers at their homes, but stayed outside. In this interview we sought the following information:

1. Their concerns with disease transmission through animals that scavenge through waste bins
2. Their opinions of the reliability of daily collection of waste
3. Their impressions of, and concerns with, the current open dumping site.
4. Their concern with the possibility of contamination of nearby fishing/farming lands due to a run off leachate.

3.2.3 Methods used to assess potential health problems

As part of the final evaluation of the current waste disposal system, we assessed major health and environmental concerns related to waste disposal. To do this, we interviewed local experts in the fields of health and geohydrology. The local experts of health were a local doctor, Khun Utan Bandi, and the local health official, Khun Jirau, who gave us their opinions of the health hazards related to the current disposal method. We interview both men simultaneously in the office of Khun Jirau. Khun Utan responded to our questions more frequently because more of our questions dealt with medical opinions of the current waste disposal system. The detailed interview form is found in Appendix G.4 Interview with retired district health officer, and the following information was sought:

1. Their general impression of the sanitation of the current disposal system.
2. Their concerns about diseases caused by flies, rodents, and other animals scavenging or living in the disposal bins or the dumping site.
3. Their opinion as to the risk of disease caused by contamination of fishing waters and farmlands with leachate.
4. Their opinion of the hazards of open-air incineration.
5. A description of hospital waste management and disposal.

For an expert opinion of the geohydrology of the local area of around the waste disposal site, we interviewed the local water officer, Suphat Buakhorm. We interviewed him at his home on a Sunday afternoon. We sought a description of soil strata and water table depth beneath the current dumping site. We also asked for his opinion concerning leachate run-off and contamination of local fishing waters and farmland.

As mentioned in the section above, we asked the Tambon Council if there have been complaints of animals, such as rats and insects, scavenging through the waste receptacles. We also asked the council and Khun Poonsin to estimate the percentage of waste disposal bins that are presently lacking covers. Through physical observation, we assessed the level of cleanliness of the tambon roads and properties. To do this, we toured the tambon's main streets in an effort to observe the amount litter that had accumulated on the side of the road. Notes were taken by hand to record this information. This information helped us to determine whether or not the current collection system is efficient and sanitary.

Another important factor in determining the sanitation of the open dumping system is to determine how it affects Sang Khom's drinking water, if at all. As mentioned above, we interviewed the local water official, Suphat Buakhorn, to determine the likelihood of leachate contaminating any groundwater, the nearby fishing water, or farmland. We also asked villagers, living closest to the waste disposal site, where their drinking water originates (i.e. underground wells). We collected a sample of the drinking water from a well located 1.6 kilometers from the waste disposal site. Sampling conditions were not sterile, but great precautions were taken to keep the sample free from contamination. These precautions included preventing the exposure of the sample to metals. To do this, we used a plastic bucket to take the water from the well and pour it into a previously rinsed amber-colored glass bottle. The bucket used for the collection of the sample is used by the villagers to collect their well water daily. The bottle was sealed with plastic wrap and rubber bands. This sample was taken to the Faculty of Environmental Engineering at Chulalongkorn University to test for levels of Cadmium, Lead, and Mercury. These three contaminants were selected due to their high level of toxicity and because they are commonly found in municipal solid waste. Test were performed, and results were given to us two weeks after we submitted the sample.

In order to assess the health concerns related to the incineration method at the waste disposal site, we first obtained a detailed description of this incineration process. Through observation, we determined the type of incineration used at the waste disposal site and the direction that the smoke was traveling at the time. We asked the Tambon Council for any information concerning the local wind patterns. We interviewed the villagers of Ban Khok, which is located 1.6 kilometers away from the waste disposal site, to determine if any villagers have had any problems with breathing due to the smoke from the incineration process. Also, we asked Doctor Utan Bandi if he had noticed any increase in breathing difficulties with the villagers. We also asked the doctor if there had been an increase in diseases being contracted and if he felt that the current disposal system had been the source of health problems within the area.

3.2.4 Methods used to assess potential environmental problems

The environmental concerns that we evaluated included the possibility of ground and surface water contamination, air pollution from incineration, and the possibility of an explosion at the waste disposal site due to gas emissions. To evaluate the potential of ground and surface water contamination, we asked the Tambon Council for a recent table of monthly rainfall rates. Using this, we determined the likelihood of leachate migrating to the groundwater table or running into nearby fishing waters or farmlands.

The assessment of environmental problems associated with the incineration system used in the tambon and at the hospital required an evaluation of the smoke and residue from the burning waste. We interviewed waste disposal worker, Khun Somchai Moonjak, and observed the incineration site to determine if the incineration process involved any environmental safety controls. We also visited the local hospital and evaluated the incineration process used for the disposal of bio-hazardous waste, which cannot be disposed of in the local waste disposal facility. We asked the doctor if the hospital kept a list of what wastes required incineration and what wastes were not considered bio-hazardous and could be disposed of with the normal municipal solid waste. This information allowed for an overall assessment of the sanitation of the hospital's waste management system

A second concern with open-air incineration at the waste disposal site and the incineration at the hospital was the disposal of the burnt residue. We asked Somchai Moonjak how the residue was currently disposed at the waste disposal site. We also observed the location where the hospital disposes of the incinerated residue.

The final environmental concern that we evaluated was the possibility of fire or explosion at the waste disposal site. To determine if such a build-up is possible at the waste disposal site, we asked Somchai Moonjak if the waste disposal site was engineered with any type of gas ventilation system and if he knew of any precautions that were taken to prevent an explosion. We also observed the waste disposal site to form conclusions as to the likelihood of explosion at the waste disposal site.

3.3 Methods Used to Assess the Feasibility of Alternate Systems

In this section, we discuss how we assessed the feasibility of introducing an alternate waste disposal system to the tambon. We were able to perform many of the required tasks prior to visiting the tambon of Sang Khom. In the first section, we detail the methods we used to assess the technical feasibility of introducing a more sanitary waste disposal system. We then describe the methods we used to assess the desirability and social feasibility of introducing an alternate system. Determining the social feasibility involved:

1) Evaluating the plausibility of educating those responsible for waste management in the tambon to design and maintain an alternate disposal system.
2) Evaluating the likelihood that a tax raise could be imposed to acquire additional funding for improvements to the waste disposal system.

3) Evaluating how the villagers will react to different suggested waste disposal systems, and whether or not the villagers will be willing to participate in personal waste reduction methods.

3.3.1 Methods used to determine the technical feasibility of an incinerator

Because it is beyond the scope of this project to determine what equipment is required to construct an environmentally sound and efficient incinerator, we limited our inquiry to pre-feasibility issues as defined in the World Bank book, Municipal Solid Waste Incinerator. We sought costs of constructing and maintaining an environmentally sound incinerator through our phone interview with Steven Sibinich, the Environmental, Safety, & Health Director of the Millbury Incinerator. We spoke with Mr. Sibinich prior to visiting Thailand. See Appendix G.5 Interview with Steven Sibinich of the Millbury Wheelabrator (Incineration with energy recovery) for the interview questions. Through the World Bank book, we determined other feasibility issues, such as the required composition of waste to allow for efficient and complete burning. We found the minimum daily input of solid waste that is required to sustain a high enough temperature for proper incineration in this book as well. Using this book, we also determined the minimum and maximum area that the incinerator could handle through population densities and per capita waste disposal rate per day.

3.3.2 Methods used to determine the technical feasibility of a sanitary landfill

Before the construction of a sanitary landfill can begin, it is essential to find an appropriate location for the site of the facility. Due to time constraints, it was beyond our ability to locate an adequate area for the landfill during our stay in Thailand. We therefore limited our methodology to a discussion with the Tambon Council concerning the issues that are pertinent to the selection of an adequate land filling site. To offer the council sound information that would enable them to select a site with minimal environmental risk, the following tasks were completed:

1) A topographical map of the area was located through the water department of the Thai Department of Mineral Resources. This map can be located in Appendix L. With this map, we discussed with the council how to select an appropriate sized area with few obstructions for excavation. We pointed out flood plain areas for the council to avoid. We discussed the importance of selecting a high elevation area to prevent the migration of leachate to the water table.
2) With the aid of the Thai Department of Mineral Resources, our team constructed a geohydrological map of Sang Khom that contains water table depths at over 20 well sites with soil strata data at two of these sites, which is located in

Appendix L – Topographical Map of Area. With this map, our team pointed out areas to the Tambon Council that had an adequate geohydrological boundary layer. The criteria for the geohydrological layer was a minimum depth of five meters of low permeability clay beneath the site and the lowest possible water table level.

3) The Tambon Council offered rainfall statistics of Sang Khom during our first visit. Due to the excess of rainfall between the months of April and September, we discussed the need for a leachate collection system in the landfill.

4) We inquired about the direction of the prevailing winds in the area of the landfill. We discussed the importance of having a substantial buffer zone between the incineration site and any residential areas.

5) Our team calculated the appropriate size that a landfill would need to be to last the required amount of time. This involved the calculation of an estimated required depth and area to support the tambon's needs for 20 years. The 20 year figure was supported in background Section 2.4.3.4 Land filling. The maximum depth of a landfill was determined using geohydrological data. The required area was determined by dividing the estimated volume of compacted wastes by this depth value. To determine the volume of compacted waste that will accrue during a 20 years period, the approximate waste disposal rate (mass of waste over time) and an estimated value of compacted waste density were required. The daily waste disposal rate is estimated to be 3,600 kilograms per day.[104] The density of the land filled waste was estimated to be slightly higher than the density of Sang Khom's non-compacted waste. Information concerning the comparison of waste density and waste composition is available in the background.

6) Finally, our team discussed the importance of selecting a site that is easily accessible to the waste disposal vehicles.

The second major task of determining the feasibility of a landfill was to determine the types of equipment required to operate and manage a relatively small landfill and the cost of such equipment. The equipment involved with land filling includes motorized and mechanical equipment used to dump, move and compact waste, and to excavate the earth. The equipment needed to operate landfills of various sizes and the number of laborers needed to operate the equipment can be found in Section 2.4.3.4 Land filling. Information concerning the size of the landfill and the number of available laborers is required to decide what type of equipment would be necessary. The cost of required equipment in the U.S. was determined when we interviewed the operators of Massachusetts' landfills and through websites selling used construction

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[104] Correspondence with Khun Tessa Sreesangkom.

equipment (See Appendix G.6 Interviews with Massachusetts landfill operators for a sample interview form).[105]

The third task was to determine the cost of the daily operation and maintenance of the landfill. Information concerning expenses was determined through phone interviews with U.S. landfill operators. These interviews took place before our departure for Thailand. Because our background research involving equipment costs was mainly from the United States, the cost estimates do not hold as much bearing when constructing our final proposal. Our information for costs were based on our interviews performed in Pratchuap. The current cost of maintaining Sang Khom's waste disposal site was utilized as a basis for estimating the cost to change to the waste disposal site (or the construction of a new waste disposal site).

The fourth task was to determine if a synthetic basal liner would be required to prevent the contamination of the groundwater by migrating leachate. To determine if the proposed site has an adequate depth of low permeability clay, we used the previously mentioned geohydrological data for Sang Khom.

The final task was to determine the appropriate pipes and other equipment used in leachate collection and gas venting. This was completed by researching landfills, and interviewing landfill operators. The specifications for equipment, pipe size, and pipe material are found in the background.

3.3.3 Methods used to determine the technical feasibility of a windrow composting facility

The third waste disposal system we considered requires the use of an outdoor composting facility to manage putrescible wastes used in conjunction with a sanitary landfill to manage non-biodegradable organics and inorganics. The technical issues we examined were the cost of equipment required to operate a small windrow facility and the waste composition requirements for effective composting. Costs of the required equipment were found online at http://www.point2.com and through correspondence with Les Huhlman, Ph.D., and the President of RRS-N.[106]

3.3.4 Methods used to determine the technical feasibility of recycling

Because of the small size of the tambon of Sang Khom, construction of a recycling facility would be well beyond the current budget; the facility would not be of high enough capacity to make the maintenance of the facility cost-effective. More likely to be feasible is the curbside collection of recyclables and shipment of these items to a nearby recycling facility. The first measure of technical feasibility of recycling is the determination of the amount of recyclable content in the waste stream. From the Chiang Mai report and the statistics for low-income nations in Table 2, our team estimated the recyclables content of Sang Khom. We then searched for a nearby (less than 30km distant) recyclables collection center. Contacting such a facility enabled us to conclude if a market is available to purchase Sang Khom's recyclables. Thirdly, we determined

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105 http://www.point2.com
106 Resource Recovery. Email: rrskw@kci.net

if funds could be acquired to purchase a new waste disposal vehicle that would dispose of the ordinary MSW, while the old truck is used to collect recyclables. We also determined if additional laborers would be required for the management, collection, and shipment of recyclables.

3.3.5 Methods used to determine the social feasibility of alternate waste disposal systems

When assessing the feasibility of alternative waste disposal systems, it was necessary to consider the desirability as well as the social implications of implementing an alternate method as well as the budget-related and technical issues. The desirability of municipally-run systems was determined by interviewing all those responsible for the solid waste management in the tambon as well as environmental experts in the village. After our presentation to the Tambon Council, which detailed our proposal for a new waste disposal system, we noted their opinions of the various systems discussed. These notes were later used to determine the what we recommended in our final proposal. Our interviews with Khun Poonsin Sreesangkom and our sponsor gave us a their perspectives concerning different types of waste disposal systems, and which would be the most desirable.

To help determine the technical feasibility of each system we considered, we evaluated the level of education required for the tambon to properly install and sustain each type of waste disposal system. Our team determined whether the tambon would need to consult a waste management expert to alter their current system or if the tambon could successfully improve their current system through the information found in this proposal.

Another consideration that we evaluated was the possibility of an increase of taxes within the tambon. If the proposed changes require funding that is above the tambon's budget, the villagers may face a tax raise. Through our first interview with the Tambon Council, we were informed whether a tax raise could be implemented and if the villagers would approve of the tax raise for an improved waste disposal system.

Finally, the we determined if the villagers will need to receive some education in order to participate in backyard composting and/or recyclables collection. We discussed this idea with Khun Poonsin and the Tambon Council as well as different methods of motivation that could be used to get the villagers to participate.

3.3.6 Methods used to determine the feasibility of waste reduction

In the Background chapter, three main types of waste reduction were mentioned: reduced consumption, backyard composting, and methane generation. The first two methods require virtually no expenditures for addition equipment, but do have some technical and desirability problems. To ascertain the feasibility of backyard composting, our team determined if there is a high enough putrescible content in the tambon's waste to make composting a viable method to reduce the amount of waste disposed at the waste disposal facility. The methodology for this was discussed in Section 3.2.1 Methods used to obtain a physical description of the current system. Through our interview with the Tambon Council, we determined if the humus end product would be put to use as a natural fertilizer. We also discovered the percentage of villagers that earn their living from farming.

To determine the feasibility of a consumption reduction program, we discussed with the tambon council the possibility of volume-based fees.

In order for backyard composting and consumption reduction to be successful in reducing the amount of waste that is disposed in the landfill, a high villager participation rate is required. Our team did not propose to the Tambon Council that they survey the population to determine the villagers' willingness to participate. We instead discussed three options that could be used to promote waste reduction and determined which options the council thought feasible to implement. The first option would be a school program to promote backyard composting. This would require the teachers to be educated first, and then relay the information to the students. Another option would be a community workshop to promote backyard composting and reduction of consumption. This would be voluntary, and might not result in a high level of participation. A final option would be having an article in the local newspaper detailing the methodology used for backyard composting. This option might not be successful if a majority of the villagers do not read a newspaper regularly. We give recommendations as to what we believe is the best method, but is the Tambon Councils decision as to which method will be used, if any.

The methane generation system is more complex than backyard composting in that it requires the purchasing of equipment. It seems unlikely that this option would have a high participation rate unless the Tambon Council could acquire the funds to purchase all of the equipment needed. Rather than discuss with the Tambon Council how to promote this method, we discussed with them the possibility of farmers being interested in producing methane as an energy source from their agricultural wastes.

3.4 Development of Our Proposal

Multiple versions of this project's final proposal were prepared to cater to the various recipients, Senator Somkid Sreesangkom, the Tambon Council, and our WPI project advisors.

Two weeks prior to the end of the project, our team delivered a presentation to the Tambon Council that covered our initial findings and recommendations. A meeting was called by the chief of the tambon so we could present our findings. Council members from the 12 villages and other stakeholders attended this meeting, which was truly a discussion of our results rather than a presentation of recommendations. At this meeting, we addressed the problems associated with the current solid waste disposal system. We offered our findings and opened the floor to their concerns, questions, and responses. We detailed suggestions that could be implemented to improve the current situation. Our team believed that most of our suggestions were technically, financially, and economically feasible for the tambon at the present time. The third part of this meeting was devoted to presenting future improvement projects that would require funding that is currently unavailable. The only visual aids used were an outline of the presentation and copies of pertinent charts, diagrams, and photographs. This outline was translated into Thai language by Khun Wanidda, a local English teacher, so we could distribute it to each person at the meeting. The original English version of this outline can be found in Appendix H - Handout used at Presentation to Tambon Council.

3.5 General Methods Used for Interviews

The interviews used to complete the project's objectives were varied in their format. We interviewed the operators of the Massachusetts landfills and the Environmental Safety and Health director of the Millbury Incinerator over the telephone. In Thailand, we were able to have individual, face-to-face interviews with Senator Somkid Sreesangkom, Khun Poonsin Sreesangkom, and the Senators wife, Khun Francesca. While in Sang Khom, Khun Poonsin translated during all of our interviews. The interview with the waste collector, Khun Somchai, and the Water Officer, Khun Suphat, were interviewed individually at their respective residences. Doctor Unto and the Public Health Officer, Khun Jirua, were interviewed together at the hospital. The interview in Ban Khok was similar to a focus group. This method was chosen because we expected to find that the villagers agreed on what the main concerns are with the current waste disposal system. The villagers at Ban Khok were selected because they were the most likely to be effected by the unsanitary waste disposal, as they were the closest villagers to the waste disposal facility.

For our interview with the Tambon Council, we were allotted a period of time during their weekly meeting in order to ask questions. Those who wished to contribute their opinions spoke freely in front of the other council members. Of the 24 council members present, between six and eight members actively contributed their opinions and answered our questions. The chairman of the Tambon Council provided most of the information we sought. Khun Poonsin acted as a translator and mediator during this meeting.

3.6 Basis for Interviews

Understanding the origin for this project has helped us focus on the true nature of the tambon's solid waste disposal problems. To determine the basis for this project, we sought opinions and regulations from these four sources: the tambon's villagers, Senator Somkid Sreesangkom, local and national laws, the Tambon Council.

Through interviews with the local population, we hoped to understand their concerns with the current system of waste disposal. We interviewed Senator Somkid to get a better grasp as to what he believes is the current problem with the system. We investigated national and local laws and regulations to determine if the current method did not meet this set of standards. We interviewed the Tambon Council to understand their concerns with the current system and how they believe it could be improved. Through our observations and knowledge from our background research, we developed our own opinions concerning the current waste disposal system. Though opinions of the interviewees are a large part of the basis for some aspects of our project, much of this project is based on our study of acceptable solid waste disposal in the United States.

4. RESULTS AND ANALYSES

This chapter contains our results and analyses of the project with respect to its three main objectives. Section 4.1 discusses the current waste disposal system in Sang Khom and analyzes the problems that result from this unsanitary system. Section 4.2 discusses the feasibility of various waste disposal systems and includes a discussion of possible waste reduction options.

4.1 Evaluation of the Current Waste Disposal System

This subsection offers a detailed description of Sang Khom's current waste disposal system and discusses the associated concerns.

4.1.1 Sang Khom's waste disposal system

During our first visit to Sang Khom, our team observed the tambon's waste disposal system. We interviewed Somchai Moonjak, one of the tambon's four waste disposal workers, to determine the details of the tambon's current process for collection and disposal of municipal solid waste. We analyzed our findings in Section 4.1.3 regarding health and environmental concerns associated with the current waste disposal system.

4.1.1.1 Current waste disposal site

The current waste disposal site is located on the border of the tambon of Sang Khom and the tambon of Phen. The waste disposal site is located approximately five kilometers from the village of Sang Khom. The site is nearest to the village Ban Khok, located in the tambon of Phen, and is about 1.6 kilometers away. The site is approximately 1 kilometer from a reservoir and from rice farms. The active dumping site is enclosed within a 30 by 30 meter area. This area is not completely isolated from surrounding areas, and our team noted that solid waste was littered on the access road and in the forested area enclosing the site. Only two sides of the waste disposal site are isolated from the forested area with a 2.5 meter high dike made from earth. This dike is used to contain the solid waste, but fails to do so because the other two sides of the site are completely open.

Upon first inspection of the site, we observed the incineration of solid waste. The incineration is open to the air, as was assumed, and occurs over the entire dumping site. There was no separation of wastes at the waste disposal site to remove wastes that should and should not be burned. The burning was very slow, and the waste was merely smoldering rather than under a vigorous combustion. The smoke had a light grey hue and produced a noticeable odor. Other than the incineration taking place, the site did not have a noticeable odor. This may have been due to the fact that much of the organic waste had been burnt. During our interview with the Tambon Council, we learned that waste is incinerated during the dry season, which falls between the months of January and April. However, distasteful odors may be present during the rainy season, when incineration is not possible. The wet, organic waste most likely releases noxious odors due to anaerobic decomposition.

The solid waste was piled two to three meters higher than ground level and did not appear to have any earthen cover. Khun Somchai Moonjak noted that the site was normally covered with earth twice a year, but had been covered only once in the past year. He stated that the tambon rents a tractor-dozer when the solid waste needs to be covered. The Tambon Council said that the dozer costs 40,000 to 50,000 Baht (910-1,140 U.S. dollars) to rent for the two landfill covering sessions. Because the waste is not frequently covered with earth, flies have become a terrible problem at the site. While surveying the waste disposal site, we could not help notice that there were an immense number of flies swarming the area.

Our team noted the composition of the remaining unburned waste at the dumping site. The majority of the visible waste consisted of metal (tin, aluminum, steel) cans. Glass bottles were also prevalent at the waste disposal site. Unburned plastics were noted, but less abundant. The remaining unburned waste consisted of yard waste, such as branches, coconut husks, and tree leaves.

Upon closer inspection of the site's layout, our team noticed that an earthen dike separated the dumping grounds from a small, near-by pit. Khun Poonsin indicated that this pit was excavated in order to collect the leachate run-off. This pit was not properly utilized because no drainage pipes were installed to connect the dumping grounds to this leachate collection area. Khun Poonsin believes that the lack of pipes was not due to poor design considerations, but due to an unwillingness to follow through with the construction process. During the rainy season, the leachate run-off drains into a two meter deep ditch on the side of the access road. Our team examined the ditch and found water and waste at its base. The significance of the inadequate leachate collection system is discussed in Section 4.1.3.

The disposal site's land was purchased by the Tambon Council from a private owner. Environmental engineering considerations were not taken into account when this site was purchased. The site was selected due to its low price and its availability, not because of its location.

4.1.1.2 Hospital incinerator

The hospital had recently built an enclosed incinerator to replace the old incinerator that had fallen apart. The old incinerator resembled a brick fireplace with a brick chimney. Emission controls were not evident when examining the incinerator. The new incinerator is much more advanced, but in no way meets U.S. EPA emission standards. Upon initial inspection, our team noted that the incineration facility was approximately 100 meters from the hospital buildings. Black smoke was emitted from the stack, making it apparent that the incinerator failed to filter out particulate matter. Doctor Utan Bandi mentioned that the hospital staff could frequently smell the smoke being produced from the incinerator.

During a closer inspection of the incinerator, our team noted that the only emission controls utilized are for the minimization of carbon monoxide gas formation. The two chambered incineration system utilized by the hospital allows for this minimization. The first chamber is a standard combustion chamber, in which a grate under the burning waste allows for air intake. The air is not forced into the combustion chamber, allowing carbon monoxide to form due to the incomplete combustion. The second chamber is used to oxidize the carbon monoxide, changing it into carbon dioxide. The first chamber was set at a temperature of 900 degrees Celsius, but when our team observed the process, the chamber was only burning at a temperature of 504 degrees Celsius. Burning at this low of a temperature can result in an excessive formation of dioxins, furans, and volatile organic compounds (VOC's).[107] The second chamber is used to destroy some of these compounds along with most of the carbon monoxide. This chamber was set for 1000 degrees Celsius but was burning at 802 degrees Celsius. This temperature does not meet the minimum temperature required to remove odorous and toxic compounds.[108]

4.1.1.3 Previous waste disposal site

Our team visited the previous dumping site, located in the village of Sang Khom, to determine how the current dumping site has improved upon the problems of the old site. This site was shut down and covered with earth approximately three years ago. Upon observation of the site, our team concluded that the site's largest environmental concern was its close proximity to fresh surface water. This body of water, which was only approximately 200 meters from the previous dumping site, is seen in Figure 20.

[107] See Background section on Incineration for further information of air pollution caused by low temperature incineration.

[108] Chiang Mai Solid Waste Management. This report noted that a temperature of 1450*F is required to minimize odorous compounds, and a temperature of 1800*F is required to minimize VOCs, furans, and dioxins.

Figure 20 - Previous waste disposal site and local water source

In the foreground of the photograph is the sunken pit where solid waste is buried; the proximity to fresh water, seen in the upper left hand corner, was the main reason for the site's closure.

4.1.1.4 Solid waste collection

To obtain a full description of the current collection practices, our team observed the collection vehicle and various waste disposal bins. Also, we interviewed one of the tambon's solid waste management technicians, Somchai Moonjak.

Khun Somchai detailed the daily collection process as well as the technical aspects of their waste disposal process. The collection crew, consisting of one driver and three collectors, works six days a week to collect the waste from the tambon's collection bins. It was approximated by the Tambon Council that there are 2,000 waste disposal bins within the tambon. The fabrication of these bins cost 350 baht a piece. The bins are of standard capacity and design, and are made from recycled rubber of old tires. Each bin was initially supplied with a rubber lid, but we observed that multiple bins either did not have a lid, or the lid was not being properly used. With the confirmation of Khun Poonsin, our project team estimated that two thirds of the bins were uncovered at the time. See Figure 5 in Section 2.4.2 The tambon's for a picture of two covered waste bins.

Khun Somchai explained that the collection crew can handle the wastes of three to four villages per day. Therefore, it takes three to four days to complete the collection for the tambon. He also stated that he had never heard any of the local villagers complain of the waste disposal collection being inefficient or wanting their garbage collected more frequently.

Each day, the waste collection vehicle handles one to two full loads of waste. According to Khun Somchai, the waste disposal team collects about one and a half truckloads per day. The collection vehicle is smaller than a standard U.S. collection vehicle, and has a capacity of only 6.2 cubic meters compared to the U.S. standard of 14 to 18 cubic meters.[109] The truck appeared to be maintained at a satisfactory level at the time we examined it. Khun Somchai mentioned that the truck does have technical difficulties occasionally, but those difficulties are usually resolved quickly. The truck is illustrated in Figure 4 in the Background.

Khun Somchai did not know the weight capacity of vehicle, but it has been estimated with the following procedure:

As discussed in the background, our team has presumed that Sang Khom's waste stream is similar to that of Chiang Mai, and has also assumed that Sang Khom is a lower-income community. Using Figure 10 - Composition of solid waste for Chiang Mai, Thailand and Table 2, our team has determined the average density of Sang Khom's solid waste is 400 Kg/m^3. Volume multiplied by density equals mass. If it is assumed that the tambon's collection vehicle dumps 1.5 loads per day, then:

$1.5 \text{ loads/day} * 6.2 \text{ m}^3\text{/load} * 400 \text{ Kg/m}^3 = 3700 \text{ Kg/day}$

The tambon disposes of approximately 3.7 metric tons of waste per day.[110]

The Tambon Council offered the figure of 10 metric tons per day as the tambon's disposal rate. No statistics or proof accompanied this statement; it was merely an estimate made by the chairman of the Tambon Council. If a truck of 6.2 m^3 dumps 1.5 loads per day to dispose of 10 metric tons per day, then the average density of Sang Khom's waste is a staggering 1100 Kg/m^3. This figure denser than that of water, and would indicate a high content of solid metal in the waste stream. Considering Sang Khom's waste stream is composted mostly of high water content food, the figure offered by the Tambon Council is probably just a poor guess.

During our interview with Khun Somchai we learned that Sang Khom had previously participated in recycling. Glass bottles and other recyclables were collected by some of the local villagers and sold for recycling. These scavengers received one Baht for three bottles until Thailand's recent economic crash. Currently, the scavengers need 20 glass bottles to be paid one Baht. Due to this change in the economy, the number of scavengers has diminished, and there is no form of recycling in Sang Khom.

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[109] J. Glynn Henry. Environmental Science and Engineering. Pg. 582.

[110] Note that the current population of Sang Khom is 8,017 people, making the per capita waste disposal rate equal to:

3700 Kg / day / 8017 people = 0.46 Kg / person / day

This per capita waste disposal rate affirms Sang Khom's classification as a lower income community.

4.1.2 Analysis of opinions regarding problems with the current system

To understand the true nature of the tambon solid waste problems, we sought opinions from these four sources: Senator Somkid Sreesangkom, Khun Poonsin Sreesangkom, the Tambon Council, and the local villagers.

4.1.2.1 Senator Somkid Sreesangkom

Our preliminary understanding of the basis for this Interdisciplinary Qualifying Project came from our sponsor Senator Somkid Sreesangkom. Our first letter from his wife, Khun Francesca Sreesangkom, indicated that an unpleasant smell and an insect problem were the main concerns with the old waste disposal site. An additional letter noted that smell was not currently a concern at the new dumping site. During our interview with the Senator, we learned that he had observed the current waste disposal site recently and believed that it needed to be improved. He did not identify specific improvements that should be made, but our team interpreted his comments to be suggesting improvements in the disposal system's efficiency and sanitation in order to protect the local populace as well as the environment in Sang Khom.

4.1.2.2 Tambon Council

Our interview with the Tambon Council offered a more detailed account of the current problems associated with Sang Khom's waste disposal system. This interview was crucial to the project's success because it is this local government, as well as Senator Somkid Sreesangkom, that will be receiving our recommendations for the improvement of the waste disposal system. Since the Council is in control of the tambon's waste disposal system, they could explain why they selected the current system and the operational details of the system. This interview also brought to the council's attention the environmental and health problems that may be associated with the current method.

During this interview, the council mentioned that the issue of poor sanitation within the current waste disposal system had been raised previously. The members of the council disagreed on the specifics of how to handle this problem, but agreed that if a project team from outside of the tambon came with a proposal for an improved waste disposal system, the villagers would be more willing accept the recommendations. According to the chief council member, the opinions of an outside source would be valued more than the opinion of locals because an outside source would be unbiased and truthful.

The council members gave our project team a copy of an official document that detailed the current waste disposal system and its problems. This document noted problems with collection and the final disposal of solid waste. The collection problems included these issues:

1. One truck did not have the capacity to efficiently manage the tambon's waste
2. The waste disposal truck breaks down too frequently
3. The collection bins are often broken, allowing waste to be littered on the street

4. The solid waste collection crew is not large enough to allow for efficient and proper collection
5. The community does not adequately participate with the current waste disposal collection practices
6. The waste is not collected fast enough, which leads to litter accumulating in the street

These problems indicate that the current collection system is not efficient. The problems above offer reasons for the large amount of litter observed on the sides of Sang Khom's roadways.

One problem noted by the Tambon Council concerning the final disposal of solid waste was that the current budget is not big enough to maintain an efficient and sanitary landfill. Another major issue noted was the infestation of rats and flies at the dumping site, which are believed to be a potential source of disease. From our observations of the waste disposal site, we also recognized these problems, but we also found other problems that will be discussed in Section 4.1.3. Because the Tambon Council's list of problems with the final disposal system does not include the problems discussed in Section 4.1.3, we have concluded that the Tambon Council is not fully aware of the health and environmental hazards associated with the current system. Despite their ignorance of some problems, the official document given to us by the Tambon Council, referenced above, stated that government agencies and private sectors should financially support a new system in order to rehabilitate the environment where the current dumping site resides. The Tambon Council therefore understands the environmental threat caused by the current open dumping system. They desire improvement but lack the funds to do so.

Our meeting with the Tambon Council expanded on the problems listed above. The council members recognized that the problems associated with current disposal system will mostly be experienced in the long-run. As the population increases, the current waste disposal site will not be able to manage the amount of waste being generated. Also, the council recognized that the leachate from the current site most likely runs into the nearby reservoir during the rainy season.

We discussed with the Tambon Council the possibility of improving the current disposal system and the methods by which it could be improved. The council emphasized that Sang Khom has a limited budget for such public works projects. The tambon has faced more urgent problems that have prevented additional money from being allocated to a solid waste disposal improvement project. The council claimed that the issue of the currently unsanitary and inefficient waste disposal system has come up before, but a decision concerning how to improve the situation could not be concluded. The council could not come to a resolution and has not recently made any attempts to change the current system. One member noted that the council would be more willing to agree to take action if an outside source (such as our project team) created a practical proposal.

Our team discussed with the council the reasons why recycling failed in Sang Khom and discovered that it is currently cheaper to purchase imported recycled materials rather than increase expenditures through the collecting, sorting, and processing of recyclables in Thailand. For this reason, local businesses have stopped purchasing used goods for recycling purposes.

During our second meeting with the tambon council, the audience offered more opinions of the problems associated with the current waste disposal system. They first stated that the problems found in Sang Khom's waste management system are experienced throughout Thailand. Also, it was stated that though the current open dumping system is unsanitary, perhaps land filling is the wrong approach to solid waste disposal. From our background research we have concluded that all waste management systems require some kind of landfill.

4.1.2.3 Khun Poonsin Sreesangkom

Because Khun Poonsin is a resident of Sang Khom, an environmental engineer, and the national coordinator of the UNDP GEF/Small Grants Programme, he was a reliable source of information and his opinions concerning the waste disposal system were highly influential to our project team as well as the Tambon Council. Khun Poonsin agreed with the Tambon Council on all of the issues concerning the problems with the waste disposal system. A more extensive account of the interview with Khun Poonsin can be found in Section 2.1.

4.1.2.4 Local villagers

Through our interview with the villagers in Ban Khok, our team concluded that the local population is concerned with the potential health and environmental problems caused by the current waste disposal system. Governmental figures and environmental experts are therefore not the only parties that would like to see improvement. The most apparent and immediate problem associated with the current disposal system is the abundance of large green flies at the site. According to the villagers interviewed, the flies found at the waste disposal site were not present in the village prior to the site being constructed. The villagers feel that these flies are not only an annoyance, but also a possible source of disease. The villagers did not have any complaints about the smell or the smoke emitted from the current waste disposal site. It is likely that the villagers do not smell the waste due to the wind patterns that carry the smells away from the village. As previously mentioned, during our trip to the dumping site, we did not observe a potent odor or an extreme amount of smoke. However, our project team encountered numerous flies as mentioned by the villagers.

The villagers are also concerned with the long-term problems associated with the improper disposal of solid waste. They agreed, and are concerned by our finding that the leachate most likely runs off into the nearby fishing waters and farmlands during the rainy season.

During our interview, we found that the villagers' drinking water comes both from rain water and from underground wells. During the rainy season, the villagers collect the rain in large ceramic container for drinking water. Once this water is gone, the villagers acquire their water from a local underground well. It is probable that the rain water collected during the rainy season is uncontaminated, but it is possible that the underground well water might be contaminated from leachate run-off from the waste disposal site.

Khun Somchai stated that he believes disease vectors are frequently accessing the uncovered waste disposal bins as well as the waste disposal site. He agreed with our opinion that the leachate most likely contaminates the nearby reservoir during the rainy season. He also mentioned that the hospital is not properly separating their wastes. According to the hospital, non bio-hazardous waste is dumped at the waste disposal site, while the bio-hazardous material is incinerated at the hospital. Khun Somchai does not believe that the separation is as thorough as possible and some bio-hazardous waste might be sorted incorrectly.

From the interviews conducted in Sang Khom, we concluded that all parties had concerns with the efficiency and sanitation of the current waste disposal system. The most common concerns were the short term issues such as inefficient collection leading to littering, and the increase in disease vector populations due to improper final disposal. The next section discusses these issues as well as the long-term health and environmental concerns associated with the current system, of which the villagers or the Tambon Council may not be fully aware.

4.1.3 Health and environmental concerns

Through interviews with doctors and through background research in the U.S. and in Thailand, our team was able to assess the health and environmental concerns associated with Sang Khom's current waste disposal system. From our findings, we have concluded that the current unsanitary waste disposal system will cause short- and long-term problems for the tambon as well as the villagers. The conclusions in this section justify the investigation of alternate waste disposal methods as discussed in Section 4.2

4.1.3.1 Leachate contamination of local surface waters

As previously mentioned, the leachate from the waste disposal site will most likely contaminate nearby fishing water and farmlands during the rainy season, lasting from May to December. Figure 21 displays the monthly rainfall totals for Sang Khom in the year of 2001.

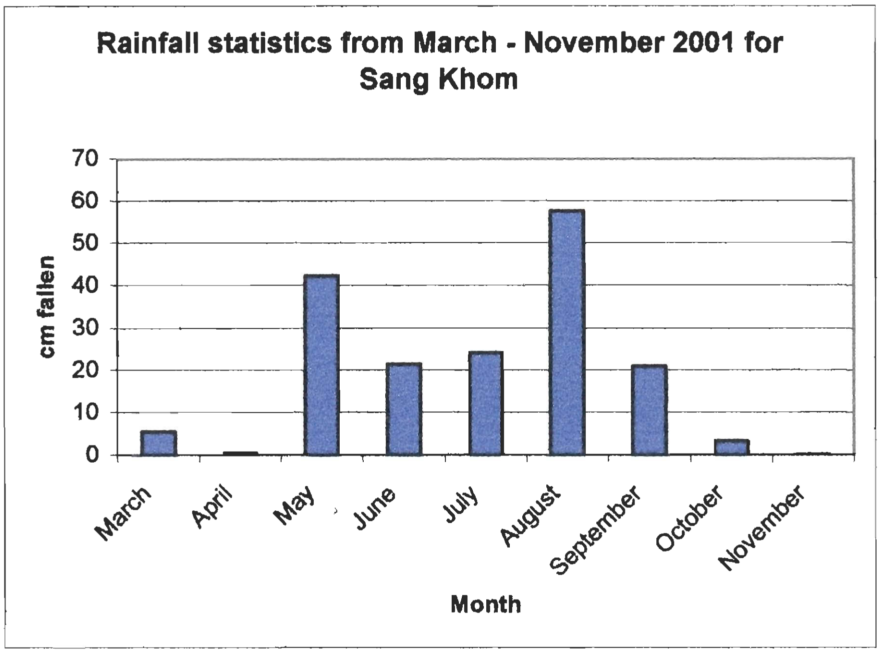

Figure 21 - Rainfall statistics from March 2001 - November 2001 for Sang Khom[111]

From this data, our team has concluded that the leachate will flood the dumping site during the rainy season and presumably pollute the nearby fishing water and farmlands due to an inadequate drainage system. Interviews with the Tambon Council confirmed that the earth cannot absorb this extensive amount rain and they mentioned that Sang Khom experiences wide spread flooding during the rainy season. Through observation of the dumping site, our team concluded that the leachate will run off into the nearby waters because of the previously mentioned poor design of the site. See Section 4.1.1.1 for a description of the site's leachate collection system.

As mentioned in Section 4.1.1.1, most of the waste remaining after incineration is metallic. During the rainy season, metals that have been dissolved in the leachate will be carried with the run-off and contaminate the fishing water and farmlands. Of greatest concern are the heavy metals that can contaminate the fish that will be eaten by the villagers. Metals such as mercury, lead, and cadmium are commonly found in a landfill's leachate, which lead us to believe that they could possibly be contaminating the local well water in Ban Khok as well as the fishing water. We did not sample any of the surface water while in the village because we visited during the dry season. During this season, it is unlikely that the run-off will reach the reservoir, so heavy metal contamination would be minimal.

During the rainy season, organic waste accumulates because incineration is not feasible. The biodegradation of this waste could possibly cause toxic organics to be released into the site's leachate. These

[111] Data provided by Tambon Council of Sang Khom.

organics could also reach the nearby water and contaminate the farmland's produce as well as the inhabiting organisms of the reservoir.

Pathogens within the water are also of great concern to this project. Because the leachate is not filtered through a layer of soil, pathogens that subsist at the site are able to enter the leachate and contaminate the reservoir during the rainy season. Pathogens are a result of various disease vectors living in the area of the waste disposal site. This problem will be discussed in Section 4.1.3.5.

To determine if the current waste disposal system was causing any health problems among the tambon population, our team interviewed Doctor Utan Bandi at the local hospital. We sought evidence of diseases caused by contaminated fish, produce in waters, and farmlands near the current waste disposal site. The doctor agreed with our concern that the heavy metals, toxic organics, and pathogens could be entering the food supply through water that became contaminated from the leachate. However, he was not aware of any specific cases that could be directly attributed to the leachate's contamination of surface water.

4.1.3.2 Leachate contamination of local groundwater

After the interview with local Water Officer, Khun Suphat Buakhorm, we concluded that groundwater contamination is less of a concern than surface water contamination. Even though a liner was not installed in order to isolate the leachate from the earth, leachate migration to the underground water supply is still unlikely. This is due to the groundwater table always remaining well below the base of the waste disposal site and because the soil located under the site works as a geohydrological boundary. Khun Suphat indicated that the water level under the site is 9 meters below ground level during the rainy season and 15 meters below ground level during the dry season. A four to five meter layer of red clay is located directly under the site and acts as a good natural geohydrological boundary. Figure 22 illustrates the soil composition and water levels found under the current waste disposal site. The natural geohydrological liner suffices in the prevention of leachate migration into the underground water supply. Therefore, it is unlikely that Ban Khok's well water will be contaminated with heavy metals or organics due to the leachate.

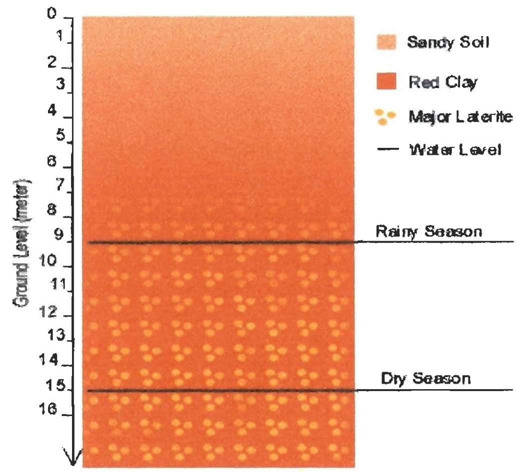

Figure 22 - Soil composition and water levels below the current waste disposal site[112]

To support this theory, we sampled well water at a site approximately 1.6 kilometers south of the waste disposal site. Test results showed that the sample contains lead, mercury, and cadmium in higher than acceptable levels for ground water used for drinking. Table 7 lists the results of the test as well as the current Thai standards. A more detailed table of drinking water standards can be found in Appendix J – Drinking Water Quality Standards.

Element	Sample value mg/L	Maximum allowable mg/L
Lead	0.500	0.05
Mercury	0.0502	0.001
Cadmium	0.301	0.001

Table 7 - Ban Khok well water sample results[113]

From the above table we see that cadmium levels are 300 times above the maximum allowable, mercury is 50 times too high, and lead is 10 times too high. These results indicate a very poor quality of ground water at this well. These levels of heavy metals are in fact dangerously high and can result in health problems such as organ damage and neurological disorders as mentioned in the background. Our team strongly suggests a further study of ground water in the area to ensure to good health of the population. Our team cannot conclude from the data above whether or not leachate from the dumping site is to blame for the high levels

[112] Data provided by Sang Khom Water Officer, Suphat Buakhorm.
[113] Testing performed by Chulalongkorn University in Thailand. The Varian SpectrAA 300/400 System was used. The samples were collected by our team in well near Sang Khom's open waste disposal site.

of heavy metals. The resulting concentrations could have numerous other causes unrelated to poor solid waste management.

4.1.3.3 Emissions from open-air incineration

It was beyond our abilities to test the composition of the emissions from the incineration process. For this reason, we can only offer the same conclusions as offered by our background sources. As mentioned previously, the site's incineration process in completely uncontrolled. We did not observe a vigorous flame; this indicates that an insufficient amount of oxygen is being supplied to the combustion. Carbon monoxide is most likely being released during the incineration process as a result. The visible smoke coming from the incineration indicates that particulate matter is being released to the environment. As mentioned previously, this particulate matter can cause breathing problems or lung cancer within the villagers. As mentioned in the background, without environmental controls, the incineration of municipal solid waste will release harmful dioxins such as NO_2 and SO_2 to the air. Both of these dioxins contribute to acid rain and are toxic to humans. The heat of combustion vaporizes some metals, such as mercury, which have low boiling points. According to Doctor Utan Bandi, the incineration process is taking place too close to the residences. However, he has never recorded any case of disease or illness that can be directly linked to the particulate or chemical emissions of the incineration. Though this open air incineration is undoubtedly polluting the environmental through air pollution, there is no evidence of an immediate threat to the local population due to toxic emissions at this time.

4.1.3.4 Emissions from hospital incinerator

As mentioned in Section 4.1.1.2, the hospital's incinerator lacks all forms of emission controls except the minimization of carbon monoxide production. The workers at the incinerator stated that the incinerator was designed and approved by the Ministry of Science, Technology and Environment. As mentioned in Section 4.1.1.2, the two-chambered incinerator was not operating at sufficient temperatures to minimize the release of dioxins, furans, and VOC's. For these reasons, our team believes that this incinerator does not adequately protect the local air. The observation of black smoke being emitted from the incinerator's ventilation stack indicates that particulate matter is being released into the air. Doctor Utan Bandi mentioned that on some days, the smoke from the incinerator reaches the hospital buildings and is noticed by the patients and staff. The incinerator's close proximity to the hospital buildings is the cause of this problem; the facility is only 100 meters from the hospital buildings. The World Bank book entitled Municipal Solid Waste Incineration indicated that the minimum distance between an incinerator and residences should be no less than 500 meters.[114] The doctor did not believe this smoke inhalation to be causing any serious problems among residents at the hospital, but was concerned with this possibility.

4.1.3.5 Concerns with disease vectors

All parties interviewed were concerned with the possibility of disease transmission through animals such as rats, insects, birds, and dogs. Of largest concern by most of the interviewees is the ever growing population of flies in and around the open dumping site. Flies are a nuisance and can possibly spread disease, such as salmonella.[115] If the tambon continues to cover the site only once or twice a year, the fly population will remain uncontrollable. Khun Somchai and Doctor Utan Bandi agreed that rats, birds, and dogs also have access to the open waste disposal site and to open collection bins. The concern with these animals was not as great as that caused by the increasing fly population.

In conclusion, our project team has deemed that the problems associated with improper solid waste disposal in Sang Khom warrant the feasibility study of alternate systems. Interviews with concerned parties, our observations, and our background research have allowed our team to conclude that the current method is unsanitary and could be a detriment to the villagers' health in the future.

4.2 Assessment of the Feasibility of Alternate Waste Disposal Systems

4.2.1 Feasibility of an engineered landfill

Through our observations of the current situation in Sang Khom, our team has concluded that the current open dumping system is a health and environmental risk. We considered both the feasibility of redesigning the current dumping site and the feasibility of shutting down the current site and constructing a more environmentally sound, engineered landfill at a new location. Because redesigning the current site would require more difficult planning than the construction of a new landfill, we limited our feasibility study to the construction of a new site.

According to the World Bank Report entitled Solid Waste Landfills in Middle- and Lower-Income Countries, Sang Khom's current system of waste disposal would be classified as open dumping, which is the least sanitary method of land filling. As stated in background Section 2.4.3.4 Land filling, engineered land filling is second to sanitary land filling in terms of environmental protection engineering. Sanitary land filling would be well beyond the allotted budget for the tambon because of the high costs of gas ventilation and leachate collection and treatment systems. An engineered landfill lacks these highly technical controls, relying on more simple methods to prevent water, land, and air pollution. Our project team has determined that an

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114 World Bank. Municipal Solid Waste Incineration, pg. 27.
115 Solid Waste Landfills in Middle- and Lower-Income Countries, pg 153

engineered landfill would be the most appropriate type of landfill for the tambon because it would reduce the major hazards that are currently present. These hazards are explained in Section 4.1.3.

As discussed in the Section 3.3.2 Methods used to determine the technical feasibility of a sanitary landfill, one of the most important considerations in the construction of a sanitary landfill is the location. There are six issues pertinent to the selection of an appropriate site. First, a topographical map should be used in order to find an adequately-sized piece of land that is on ground high enough to decrease the likelihood of leachate migration into the aquifer. The site should not be placed in wetland areas or in a low-lying area that acts as a flood plain during the rainy season, as this can cause an increase in the amount of leachate present. The site should also be relatively flat in order to allow for ease of excavation. The map in Appendix L – Topographical Map of Area was acquired from an official topographical map was acquired from the water department of the Thai Mineral Resources Department and displays elevations around the Sang Khom area. The Tambon Council should be able to use this map in order to locate areas that meet the criteria listed above.

Secondly, the Tambon Council must select a site that has an adequate geohydrological barrier that can prevent leachate from migrating to the aquifer. At least three meters of low permeability clay is considered an adequate thickness.[116] A site with a very low water table should also be selected to further minimize the likelihood of leachate migration. The map in Appendix L is covered with 22 numbered points, which are well sites that have had the levels of the water table recorded. Two of these points, numbers 10 and 11, have also had soil strata data taken. Table 8 contains the data on each point's water table level and soil strata type. The seasons of test dates are variable; some tests were performed during rainy seasons and some were performed in dry seasons. The water table level will generally be higher during a rainy season than during a dry season. Because extensive soil strata data was unavailable, the most useful information to be taken from this chart is the water table depths. Sites 1 and 2 were taken during dry seasons and have reasonably low water tables. Sites 5 and 6 were taken during rainy seasons and have a reasonably low water tables for the rainy season. Because water table levels are generally higher during rainy seasons, sites 5 and 6 may be appropriate choices to consider building a landfill because they have natural boundary layers that would serve as protection for the aquifer.

[116] World Bank. Solid Waste Landfills in Middle- and Lower-Income Countries, pg 87.

Well Site # #	Test Date Month-Year	Depth to water table Meters	Thickness of water layer Meters	Water flow rate Cubic meters/hour	Top soil	Clay	Shale	Siltstone
					Depth of layer in meters			
1	Dec-2532	8.49	13.34	10.29				
2	Feb-2515	9.55	11.59	10.69				
3	Feb-2515	5.27	17.93	10.57				
4	Nov-2518	5.76	19.27	5.52				
5	June-2520	8.49	18.51	5.04				
6	June-2520	8.16	7.65	7.12				
7	Jan-2522	5.10	16.80	1.36				
8	July-2525	5.10	17.10	2.27				
9	Apr-2526	3.30	7.17	7.80				
10	Apr-2507	2.63	4.17	18.01	0	4.5	19.8	0
11	June-2528	6.60	9.90	4.09	1.5	0	4.5	54.9
12	Mar-2515	5.45	19.22	10.57				
13	Nov-2518	3.30	18.00	2.27				
14	June-2520	3.45	17.55	5.04				
15	Feb-2523	7.50	12.60	2.73				
16	Feb-2524	3.60	11.70	1.36				
17	Mar-2526	3.60	11.40	1.14				
18	Mar-2526	3.07	12.77	7.12				
19	Apr-2526	6.30	9.30	1.59				
20	Feb-2515	4.50	12.90	12.82				
21	Dec-2512	4.24	3.69	12.13				
22	Mar-2526	5.84	7.96	2.88				
23	Jan-2522	3.45	22.61	7.12				
24	Jan-2522	8.65	18.31	5.04				
25	Jan-2522	4.56	17.25	7.12				
26	Jan-2522	3.90	12.30	1.36				
27	Dec-2512	3.83	23.30	10.80				
27	Feb-2524	6.00	6.30	10.57				

Table 8 - Geohydrological data for Sang Khom.[117]

[117] Data provided by the Water Department of the Thai Department of Mineral Resources

The third consideration is the possibility of leachate formation at the site of the landfill. Because Sang Khom experiences a rainfall rate of greater than 20 centimeters of rainfall for five months out of the year, it is highly probable that leachate will form. This means that a leachate collection system will be needed for proper sanitation of the landfill.

Fourth, the landfill site should be no less than 1500 meters upwind from residential areas. The prevailing wind direction in Sang Khom is northerly. The Tambon Council will need to take that into consideration when choosing the final site for the landfill.

The fifth consideration is size, which can be found by an approximation based on the assumption that Sang Khom population growth rate is the same as that for Thailand. As referenced in Section 2.1

The Kingdom of Thailand and the Tambon of Sang Khom, Thailand's population growth rate is 0.9 percent per year. Using the following equation, we were able to estimate the tambon's yearly disposal rate:

$$\textbf{Population} * (1 + \textbf{annual growth rate})^{N} * \textbf{Waste generated (person per day)} * \textbf{Number of days in year} = X$$

Using this equation, we were able to come with the following formula to determine the amount of waste disposed of in 20 years:

$$\sum_{N=1}^{20} \textbf{8017 persons} * (1 + 0.009)^{N} * [\textbf{0.46 Kg/(person / day)}] * (\textbf{365 day / year}) = \textbf{30,962,250 Kg}$$

Where N is equal to years from the present. An N of 20 years was chosen as a basis because that is the expected lifetime of a landfill according to Thai standards. This figure was acquired from the Lord mayor of Pranburi, Pornthep Visutvatanasak, whom we interviewed about Pranburi's waste disposal system. Figure 23 displays the waste disposed of for each year. By summing the waste disposed each year, the total waste disposed in 20 years equals nearly 31,000 metric tons. The figure below includes a trend line to illustrate that the waste disposed is not a linear function of time.

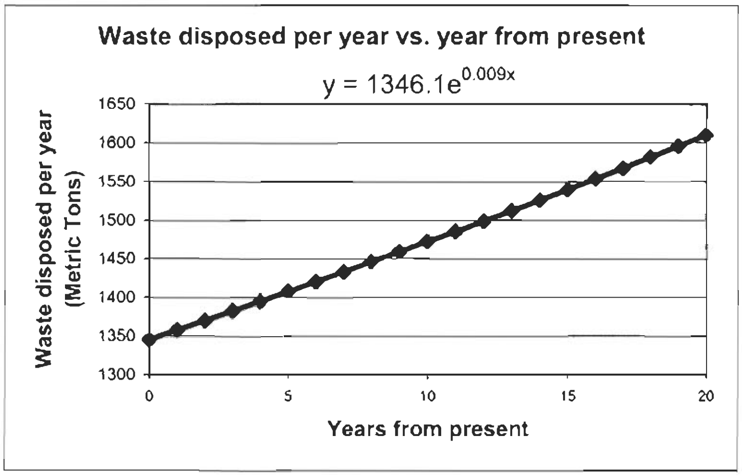

Figure 23 - Waste disposal rate

The depth of the site should be similar to the depth of the previous site, which is approximately 2.5 meters. This would decrease the likelihood of leachate migration to the aquifer. To decrease the required land area, the waste could be dumped into cells on top of this basal cell layer. For this calculation we have assumed that two cells of 2.5 meters thickness are used. Finally, we have assumed that the solid waste in the landfill will be compressed to at least 500 Kg per cubic meter. With this data the following calculation will give the area required for 30 years worth of compressed solid waste.

$[47,900 * 10^3 Kg / (500\ Kg / m^3)] / (2.5\ m/cell * 2\ cell) = 19160 m^2$

Also, we must consider that about 25% of the space goes to cover soil. Therefore the area required for this landfill is:

$19160 m^2 * 1.25 = 23950\ m^2$ = 239.5 acres

The final consideration for the location of the new landfill is the ease of access of waste disposal vehicles and equipment. The Tambon Council should select a site that is not too remote and already has well maintained roads that run close to the proposed site.

The second major task in the assessment of feasibility for this landfill is the determination of types and costs of equipment needed to construct and maintain a small engineered landfill. As stated in the background, a landfill that handles less than 50 tons per day will manage with one tractor dozer.[118] The tractor dozer can be used to excavate earth in the construction of the new site, to move the waste and compact it slightly, and to cover the waste daily with soil. With the tambon's current budget it is not possible for Sang Khom to purchase a dozer for this use. During the second meeting with the Tambon council, we learned that a used dozer should cost between 200,000 and 300,000 Baht (4,500 and 6,800 U.S. dollars).

As mentioned in the background the tambon rented a dozer to construct the current site and rents it once or twice a year to cover the wastes. If a new disposal facility were constructed, the dozer would have to

[118] World Bank. Solid Waste Landfills in Middle- and Lower-Income Countries, pg. 137.

be rented to excavate the site. The only way to maintain the daily coverage of the exposed waste with dirt is to do so manually because Sang Khom cannot purchase a dozer. One or two men could be hired to spread the waste and to cover it daily with six inches of native soil.[119]

The new site, or the redesigned current site, must be operated properly to maintain the landfill in order to ensure a high level of sanitation. As mentioned previously, operations of large U.S. sanitary landfills are inapplicable for Sang Khom. For the small engineered landfill, the main operation considerations are daily coverage with soil as discussed above, the prevention of fires that can spread to surrounding areas, and preventing human or animal scavengers from accessing the site. These scavengers can spread disease just as the flies and birds that live at the current waste disposal site. The daily earth covering may prevent flies, birds and rats from accessing the site, but humans, dogs and other large animals may attempt to access the wastes. The human scavengers are looking for recyclable goods that can be sold, while the other animals are seeking food. Both types of scavenging can spread disease to nearby villages. A round the clock guard may be necessary to prevent human scavenging. A barbed wire fence and lockable entrance gate could be constructed to prevent human and large animal access to the site.

The fourth task mentioned in the methodology is the assessment of the need for a synthetic basal liner. Because we are proposing only an engineered landfill, as opposed to a sanitary landfill, the basal boundary layer does not need to be perfectly impenetrable to the leachate. The basal layer can be the natural soil strata under the earth as long as it meets requirements mentioned above. The soil strata data available from the Thai department of mineral resources was not adequate in determining the permeability of lands around Sang Khom. If a new site is not constructed, and the current site is improved upon, a synthetic liner would not be needed because there exists a large (greater than five meters) layer of low permeability red clay beneath the waste disposal site. Also, the water table is greater than nine meters below the surface year round. The existence of the large clay layer, and the minimum depth of water table indicate that the geohydrological boundary minimizes the possibility of leachate migration to the water table.

Even if a new site is constructed that does not have an adequate natural geohydrological boundary layer, Sang Khom does not have the funds available to purchase a modern synthetic basal liner system. An interview with Hank Van Laarhoven, manager of the Crapo Hill Landfill in Dartmouth, Massachusetts, gave us price estimate of a high quality liner. The liner is made of 1 foot of impermeable clay, a 60 mm layer of HDPE, a drainage layer, and another 80mm layer of HDPE. This liner system costs 230,000 dollars per acre to install. Sang Khom could purchase a simpler liner system such as the one used at Hua Hin's sanitary landfill. A 1mm thick HDPE liner is used and cost 120 baht (2.73 U.S. dollars) per square meter.

The final task mentioned in the methodology is the determination of pipes to be used to properly drain the leachate and the vent gases. Gas ventilation will probably not be a major concern for the Sang

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[119] Ibid., pg. 142.

Khom's small landfill, and requires additional, more complex technical considerations. A leachate drainage system is relatively simple to create. First the base of the new landfill must be sloped so that the leachate will flow and pool in certain predetermined areas. In these areas gravel must surround 150 millimeters inner diameter perforated PVC piping. During our second meeting with the tambon council, we learned that these pipes should cost between 400 and 500 Baht per 4 meter length section (9.09 to 11.46 U.S. dollars). The perforations should be small, smaller than the diameter of sand to prevent clogging.[120]The gravel increases the high permeability surface area around the PVC pipe to increase the flow rate from surroundings areas to the pipe. The PVC pipes should be laid down so that the draining leachate will flow through the pipes to a lower, isolated collection area. Because the treatment of the leachate requires expensive technology, the collection area should be open to the air to allow evaporation. It is important for the collection area to be isolated to prevent floods or runoff into nearby wetlands or water systems. This isolation could be as simple as an area enclosed with earthen dikes, or could be improved upon with a HDPE liner.

Most persons interviewed agreed that the prevailing winds headed northward. Background sources have indicated that a landfill should be at least 1,500 meters downwind from residences.[121] We therefore explained to the council that the landfill site should be located at least 1.5 kilometers south of any residential area.

If a new site is not constructed and the old site is simply improved upon, some of the above criteria do not need to be considered. The discussion of equipment needed is important as is the daily operations discussion. The discussion of the synthetic basal liner is most likely not applicable in the redesign of the site. The construction of a leachate confinement system is one of the most important aspects of the redesign of this dumping site. It will be virtually impossible to install PVC pipes beneath the already buried waste. More feasibile is to landscape the current site to allow the leachate to flow into the previously excavated collection pit. This landscaping entails the enclosure of the site with earthen dikes. A dirt ramp could then be constructed to allow the dump truck to back into the site and drop the wastes into the landfill. A trench could be dug into the dike that separates the disposal site and the leachate collection pit. This would allow leachate to flow into the collection pit provided that the base of the pit is made lower than the base of the disposal site. This redesign should prevent the leachate from running off into nearby fishing waters and farm lands, and force it to enter the newly installed drainage system.

An engineered landfill involves covering the waste daily, a system to control the removal of leachate, spreading and compacting waste in layers prior to covering the waste, and an improvement in the isolation of the waste from nearby water supplies. This improvement upon the current method of open dumping, if implemented properly, would drastically reduce the local concerns with the sanitation of the local waste disposal system. The required steps for developing an engineered landfill do not call for expensive

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[120] World Bank Techincal Report. Solid Waste Landfills in Middle- and Lower-Income Counties. Pg. 54.
[121] J. Glynn Henry. Environmental Science and Engineering. Pg 597.

equipment, but merely more planning and maintenance. Covering the waste daily would reduce the possibility of disease vectors accessing the waste. A system to control the removal of the leachate will alleviate the current concerns with local water contamination. The local waters include drinking water, fishing water, and water used to irrigate farmlands. Spreading and compacting the layers would help reduce the overall volume of the waste being disposed of in the landfill. Locating the landfill in an area where it is isolated from all water supplies would also give the villagers comfort concerning the possibility of water contamination.

A landfill is necessary for all types of waste disposal systems. Because recycling cannot be utilized as a primary waste disposal method, it must be used as a supplementary system. No matter how recycling is used in a waste disposal system, a landfill still is required for the disposal of waste by-product. When composting is the primary method, a landfill is necessary for the disposal of inorganic material. Even when incineration is the primary method of waste disposal, a landfill is needed to properly dispose of the residue left behind after the waste has been incinerated.

4.2.2 Feasibility of municipal collection and shipment of recyclables

After researching the possibility of creating a municipally-run recycling facility, we determined that a tambon-wide recycling system would be inefficient and infeasible at this time due to cost. Shipping the recyclables would require the purchase of another vehicle for transportation to the nearest facility, which would be beyond the budget's capability. From our interview with Somchai Moonjak, we discovered that the market for recyclables has diminished over the past three years. Currently, the market-value for 20 glass bottles is approximately one Baht, while three years ago, three glass bottles were worth one Baht. In the past, there were many people who collected recyclables for profit. The number of scavengers has dropped greatly over the past few years since it is not worth the time for most people. If a market were more prevalent, we would have performed a feasibility study to determine if municipally-run recyclable shipping system would be worthwhile for the tambon. If the market for recyclables were more favorable, we recommend that the tambon consider taking advantage of the opportunity to reduce local waste, and ship recyclables to a nearby processing or purchasing facility. Our team has been unable to find such facilities in the province of Udon Thani. If the Tambon Council believes that recycling is an option, we suggest that they perform a study to make sure the costs involved would be worth the benefits.

4.2.3 Feasibility of municipally-operated windrow composting facility

A windrow composting facility would improve the current problems with waste disposal in Sang Khom, but it is not the best option. The equipment required for such a facility are beyond Sang Khom's available budget. Les Kuhlman, Ph.D. and President of RRS-N, indicated that a small turner and shredder would be needed to manage a windrow composting facility for such a low rate of waste generation as is seen in Sang Khom. Prices of this equipment were found online at http://www.point2.com and through correspondence with Les Kuhlman. Both pieces of equipment would cost between 20,000 to 50,000 U.S. dollars. This expenditure is even greater than the expense incurred to purchase one dozer tractor for the proposed landfill.

Also, after constructing a windrow composting facility, workers would need to be trained to properly operate the system. Sang Khom may not have the available work force to hire workers to operate a windrow composting facility as well as the proposed landfill.

According to both the Tambon Council and Poonsin Sreesangkom, there seems to be a demand from local farmers for the composting by-product, humus, to reduce the need for the inorganic fertilizers that are currently being used. It was also mentioned by Khun Poonsin that the local villagers are worried that these inorganic fertilizers might be harmful to use on farms. Since it is obvious that humus created by composting methods would be a product that could be readily put to use by farmers, it appears beneficial to implement some form of composting system in Sang Khom. Because backyard composting would produce humus and cost significantly less than windrow composting, a municipally-operated windrow composting facility would not be necessary.

4.2.4 Feasibility of an environmentally sound incinerator

After evaluating the tambons budget, it is apparent that an environmentally sound incinerator is not a plausible option. Our team has found no evidence that incinerators, which operate in accordance to the standards of the U.S. EPA, exist in Thailand. It therefore seems unlikely that one would be approved for construction in the near future.

For an environmentally sound incinerator to be economically feasible, there should be an input of at least 240 tons of waste per day.[122] To achieve this generation rate, Sang Khom would need to combine its waste with that of a much larger area, though an area that would generate this much waste may be too large for economically feasible collection and transportation of this waste. As mentioned previously, a collection vehicle should travel no more than 30 kilometers from the point of pickup to the point of disposal. The Millbury Incinerator in the state of Massachusetts cost 130 million U.S. dollars in 1987 to construct, and currently manages 1,500 metric tons per day.[123] A proposed incinerator in North Kingstown, Rhode Island would have cost 160 million U.S. dollars in 1989 and would manage 710 metric tons per day.[124] Both of these incinerators handle well over the amount of waste per day that is disposed of in Sang Khom. Also, both of

[122] World Bank. Municipal Solid Waste Incineration.
[123] This information came from Steven Sibinich, the Environmental, Safety, and Health Director at the Millbury Wheelabrator in Massachusetts.
[124] Providence Journal. July 18th, 1989. Pg A-3. This incinerator was never constructed.

these incinerators cost well over 100 million U.S. dollars, which is well above the tambon's given budget and all grants that could be provided by the organizations discussed previously

As shown in Table 2, the tambon's garbage has a high moisture content, possibility as high as 80 percent by weight. In order for the waste to combust, this water must be evaporated. The energy that goes into this evaporation may surpass the heat output per mass of the combusting garbage. In this case, the garbage would not burn. In fact, garbage with moisture contents as low as 56 percent may not be able to sustain combustion.[125] Two ways to avoid this problem would be either to dry the waste prior to incineration or to use an auxiliary fuel. Both processes require additional equipment that would add to the overall expense; this is further evidence of the infeasibility of constructing an environmentally sound incinerator in Sang Khom.

Another problem associated with the introduction of incineration to the tambon is that a technically trained staff would be required to operate the equipment. It is doubtful that the villagers could receive a high enough level of training to adequately operate and manage a large incinerator. Managers of incinerators in the U.S. have advanced engineering degrees. Professional engineers would need to be hired to work at the facility in order to ensure proper plant operation. Without highly skilled workers, the incinerator might run the risk of breaking down due to misuse. From all of this information, our team has concluded that it would be highly infeasible for the tambon to have an environmentally sound incinerator as their primary means of waste disposal.

4.2.5 Feasibility of personal waste reduction

The best improvement any community can make to a waste disposal system is to reduce the amount of waste that is produced. Waste reduction is the most preferred waste disposal method according to the U.S. EPA hierarchy discussed in the Background chapter. . Section 2.4.5 Waste reduction discusses three types of waste reduction: reduced consumption, backyard composting, and methane generation. The first two methods require virtually no expenditures for addition equipment, while methane generation would require the acquisition of a special tank to contain the methane gas.

To consider the feasibility of reduced consumption, we examined the change in the consumption in recent years. In our interview, Poonsin Sreesangkom expressed his opinion that rural villagers in Thailand are becoming less concerned with conservation of materials. Instead of using banana leaves and other natural packaging products, they have begun to use a larger percentage of man-made products such as Styrofoam and plastics. These newly adopted packaging materials make disposal more difficult and are not as easily biodegradable as organic materials, which do damage to the environment. The villagers have become accustomed to choosing the easier option as opposed to an environmentally safe option. These lifestyle

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[125] Joo-Hwa Tay. Energy Generation and Resources Recover from Refuse Incineration. Pg 109.

changes are a result of an increase in personal wealth and a result of Thailand's industrialization and commercialization. The greater wealth has caused an ambivalence to amount of waste that is thrown out, while industrialization and commercialization have altered the types of materials available to Sang Khom residences to consume and dispose. Because of this change in lifestyle, it may prove difficult to encourage the villagers to return to old ways of doing things.

One way that the Tambon Council might consider attempting to promote reduced consumption is to mandate a volume-based fee for waste disposal. By doing this, it would encourage the villagers to reduce the amount of waste that they produce. One problem that could arise from volume based fees in the growth of illegal dumping. The tambon council must consider this problem before it attempts to make such a mandate on its villagers.

Backyard composting could be the greatest benefit to the tambon's waste disposal system if a large enough percentage of the population would become involved. Backyard composting would allow the villagers to continue with their new lifestyle of increased consumption; it would only require the villagers to sort their waste into compostable and non-compostable categories. The non-compostable waste would then be collected by the waste disposal team and disposed of in the landfill. The compostable waste would be placed in a pile located in that person's yard. When the composting process is complete, the villagers can then use the end product, humus, to fertilize their farms, or can sell the humus to other villagers who have a need for the humus. According to Poonsin Sreesangkom, 90 percent of the tambon's villagers earn their living from farming, so it seems very likely that composting in order to produce a fertilizer as humus would be very desirable to the Sang Khom villagers. Approximately 60 percent of the waste in Sang Khom would be able to be composted according to Chiang Mai study mentioned in the background. If all of the villagers in the tambon were to participate, waste being brought to the landfill would be reduced by about 60 percent.

Methane generation is more complex than backyard composting in that it requires equipment. It seems unlikely that this option would have a high participation rate unless the Tambon Council could acquire the funds to purchase all needed equipment. This option was never discussed with the Tambon Council.

In order for backyard composting and consumption reduction to successfully reduce the amount of waste disposed in the landfill, the villager participation rate must be high. Our team did not propose to the Tambon Council that they survey the population to determine the villagers' willingness to participate. We instead suggested that the three following methods be used to promote the three waste reduction options:

1. A school program to promote backyard composting
2. A community workshop to promote backyard composting, and reduction of consumption
3. An article in the local newspaper detailing the methods of backyard composting.

A detailed discussion of these three options is listed in the recommendations section.

5. RECOMMENDATIONS

This chapter details our final proposal for the improvement of the waste disposal system in the tambon of Sang Khom. The proposal includes all waste disposal options previously discussed in the results. This section discusses the different options and their timeframes, benefits, and drawbacks. We evaluated expenses, villager participation, and technical feasibility and make recommendations concerning each option. We discuss methods for implementation of this proposal as well as possible sources for funding. Ultimately, the Tambon Council is responsible for deciding on a course of action and acquiring the funds for its implementation.

5.1 Redesign of the Current Landfill and Relocation of a Future Landfill

Our team has concluded that Sang Khom should first redesign, and eventually relocate, its land filling site in order to eliminate the environmental hazards caused by the system's current management practices. In order for immediate results to occur, we recommend that the current site be redesigned and managed more effectively. To improve the current site's level of sanitation, a simple solution would be to cover all exposed waste daily. If daily cover is not possible, any covering occurring more frequently than twice a year would yield an improvement in the level of sanitation. This would reduce the number of disease vectors currently accessing the site and ensure that there would not be any complaints of foul odor. These options involve a minimal cost compared to the construction of a new waste disposal site. Although these recommendations would improve upon the current situation, they would not solve all of the problems associated with the current waste disposal system.

According to the Tambon Council, the current open dumping site will no longer be able to support the tambon's waste within a few years. At this point, an engineered landfill could be constructed using the suggestions included in this report. The construction of a new site would require additional funds to be used for purchasing land and either purchasing or renting a dozer to excavate the site. It is understood that the tambon has a limited budget and cannot make large investments at this time. A solid waste management expert should be consulted before any major construction is begun. One contact option that may prove useful is the consulting firm hired to design Prachuap's proposed sanitary landfill.[126]

5.1.1 Redesigning the current site

Redesigning the current site is considered to be the most technically and financially feasible option at this time. The following suggestions could be implemented to minimize the health and environmental hazards present at the current dumping site.

[126] The consulting firm used was: Sena Development Co., LTD., telephone number: 662-9544615-8.

5.1.1.1 Create leachate containment system

As part of the redesign of the current site, an adequate leachate containment system should be constructed to prevent the possible pollution of local water. The site could be landscaped in order to allow the leachate to flow into the previously excavated collection pit. This landscaping entails the enclosure of the site with earthen dikes. A dirt ramp could then be constructed to allow the dump truck to back into the site and drop the waste into the landfill. A trench could be dug into the dike that separates the disposal site and the leachate collection pit. This would allow leachate to flow into the collection pit provided that the base of the pit is made lower than the base of the disposal site. This redesign should prevent the leachate from running off into nearby fishing waters and farm lands, and force it to enter the newly installed drainage system.

5.1.1.2 Cover all exposed waste with soil daily

We suggest that the currently exposed waste at the current site be covered with 15 to 20 centimeters of compacted, native top soil. Once this occurs, we recommend that that each day's dumped waste is covered with the same amount of native top soil. A dozer tractor is ideal for this purpose, but at the present time funds are not available for its purchase. For a site of this size, the soil covering can be applied manually by one or two laborers. They could use rakes, shovels, and wheel barrows to perform this work. Each day, the laborers would position dumped waste into a small pile. If the waste is spread out over the entire dumping site and is not compacted in small piles, it will be virtually impossible to cover all exposed waste with 15 centimeters of soil each day.

The Tambon Council mentioned that the current site will be at maximum capacity within four years. At this time, the site should be environmentally isolated to prevent further problems due to the leachate run-off. Once the current site is ready to be closed down, we suggest that at least 50 centimeters of low permeability clay be compacted over the site to minimize the amount of water that can permeate the buried waste. Using this final covering system would cause most of the rain water to simply run off the surface of the clay into the leachate containment ditch.

5.1.1.3 Cease open-air incineration at the site

A simple option that will prevent air pollution at the current waste disposal site is to cease all open-air incineration. At first, this may cause the landfill to acquire more waste, as none will be burned away by the incineration practice. However, once the villagers begin to compost their organic waste, as is proposed in section 5.5, the amount of waste taken to the landfill will decrease. This may prolong the lifetime of the current landfill, giving the tambon more time to acquire funding for the construction of an engineered landfill.

5.1.2 Constructing an engineered landfill

If funds become available to purchase equipment to construct a new, engineered landfill, the suggestions listed in Section 4.2.1 combined with the following suggestions should be considered to ensure the protection of the local environment.

5.1.2.1 Selection of a location for the landfill

If a new waste disposal site is to be constructed, the Tambon Council must consider issues such as leachate control, distance from villages, and proximity to flood plains when looking at possible sites. As mentioned previously, the only issues considered in the site selection for the current dumping site were the cost of the land and its availability. This method of selection is unsatisfactory in the standard design of an engineered or sanitary landfill. Using the map included in Appendix L and the data included in Table 8, the Tambon Council should be better able to select a site that adequately protects the population of the tambon and the local environment. A detailed discussion of considerations made when selecting a landfill site is found in Section 4.2.1

5.1.2.2 Considerations for leachate control

The technical considerations for an engineered landfill's leachate control system are more complex than what has been suggested to improve the current site. It would be difficult to install a system of PVC pipes into a landfill that already has a large depth of buried wastes. First, we suggest that a synthetic liner, such as the 1 mm HDPE liner used at the Hua Hin sanitary landfill (Cost: 120 Baht per square meter), be installed to cover all areas where solid waste will be piled; there was no such liner installed under the present dumpsite. This liner should be laid down with a minimum of 30 centimeters of soil compacted above to prevent puncture from heavy equipment.

Next, the site should be enclosed by a two meter wide and two meter high earthen dike to restrict leachate flow to the drainage ditch located beside the current access road. An earthen ramp should be built up using a dozer, in order to allow the dump truck access to the site.

Finally, the slope of the waste disposal site must be analyzed to determine which direction the leachate will flow. Perforated PVC pipes should be installed to collect the leachate. Background sources have indicated that these pipes should be no more than 30 meters apart. The pipes must be installed with a gradient of at least 1 percent to create proper flowing of the leachate into a designated area. It is also suggested that additional pipes be installed perpendicular to the original pipes. These pipes will be connected to the original pipes in order to increase the overall effectiveness of the drainage system. Figure 15 in the Background chapter resembles a system that could be used in the new engineered landfill. This type of base could be implemented into the next waste disposal site, which would greatly enhance the efficiency of the system.

We have prepared some details for the installation of this piping system. First, shallow and wide trenches should be dug where the piping will be positioned. We suggest the trench be dug to allow all of the PVC pipes to be exposed rather than block the bottom half with dirt, preventing adequate water flow. Parallel pipes should be laid ~30 meters apart, and Perpendicular pipes should be connected to these pipes and have ~30 meter separation. As discussed in the Background Chapter, these pipes are usually 150 millimeter Inside Diameter (ID) perforated PVC piping. The perforations should have a diameter small enough to prevent clogging with sand particles. A 20 cm thickness of gravel should surround the pipe. Having a barrier of gravel makes is easier for leachate to enter the pipe, and prevents sand or waste items from clogging the perforations. Located above the gravel should be a 30 cm layer of native soil, in which the waste is then placed.

5.1.2.3 Considerations for soil cover of land filled wastes

The discussion in Section 5.1.1.2 is still pertinent to the daily operation of an engineered landfill, but disease vector access and leachate migration could be further prevented by the use of the cell method. In this method, each cell is a volume of waste that is enclosed by a layer of dirt that is thicker than the daily soil cover layer. The cells should be of substantial size, measuring six meters by greater than six meters. It is recommended that each cell be two meters high, and two to four cells could be stacked vertically. Each day waste is piled in a small area of the cell and then covered with 15 cm of soil. During successive days, waste and soil is piled to allow the cell to grow lengthwise. When the cell is at the desired size, 30 cm of soil is compacted above all parts of this section to enclose one cell. The sanitary landfill at Hua Hin uses a four cell stacking method. Multiple cells exist side by side at the base. Four such levels exist, stacked on top of each other. The following diagram illustrates the design of one cell.

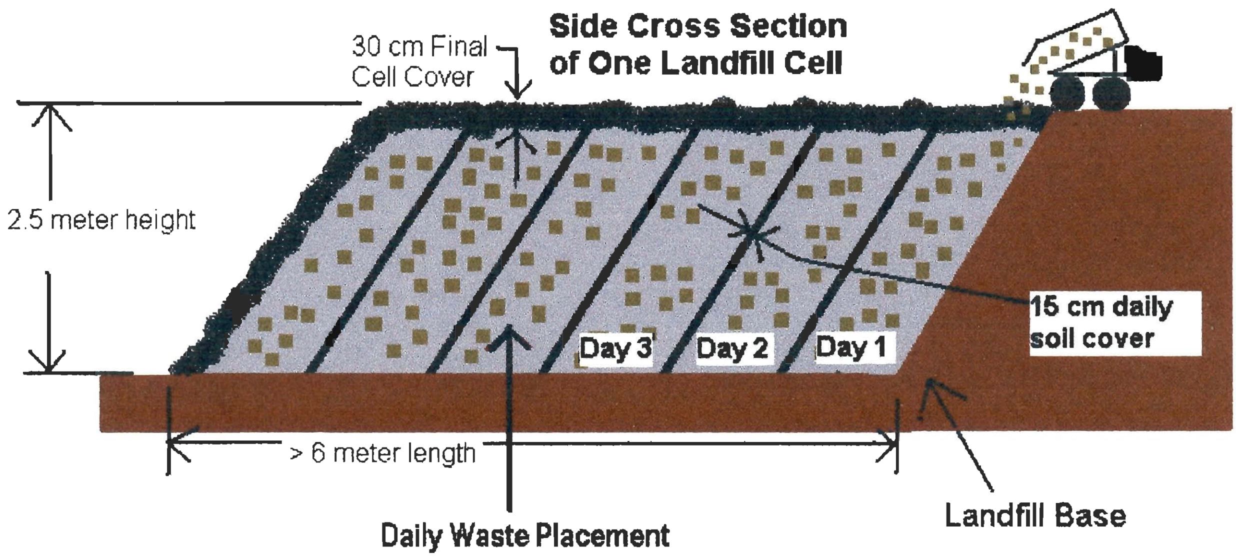

Figure 24 – Side Cross Section of Landfill cell

5.1.2.4 Consideration of a gas ventilation system

Due to the small size of Sang Khom's current dumping site, gas ventilation is not practical. However, if a new site were to be constructed and were to include a greater amount of biodegradable wastes from a larger populace, a gas ventilation system should be implemented; section 5.6 describes which areas could become potential partners with Sang Khom in future waste disposal projects. The venting system is similar to the leachate drainage system in that perforated pipes should be installed vertically and be surrounded by gravel in order to increase the gas flow from the surrounding wastes and prevent clogging of the perforations.

5.2 Improve Efficiency of Solid Waste Collection

Improving the efficiency and sanitation of Sang Khom's waste collection is just as important as improving the site at which the waste is dumped. As mentioned previously, our team concluded through interviews and through observation that the collection vehicle, collection crew, and collection bins were not as efficient as they can be in the collection and disposal of the tambon's waste. This less than optimal effectiveness was illustrated by the large amount of litter along major and minor roadways in Sang Khom. This could be due to the inefficient size of the collection vehicle, or illegal dumping. The methods used to minimize illegal dumping are discussed in Section 5.3

5.2.1 Purchase larger collection vehicle

Our interview with Khun Somchai indicated that the current collection vehicle broke down often. We also discovered that the truck must make more than one collection dump per day. Though funds are not currently available, our team believes that a newer, larger dump truck that has a capacity of 14 cubic meters should eventually be purchased to replace the old vehicle. A larger vehicle may be able to collect all the waste on a daily route without making multiple stops at the dumping site to empty the truck. The old truck could then either be a backup for the new truck or sold.

5.2.2 Acquire covers for all household collection bins

We recommend that the Tambon Council acquire covers for the household bins that do not have them. At our second meeting with the Tambon Council, the members of the council stated that the reason that many people do not have lids for their household bins is because these bins were not all purchased at the same time. The first set of collection bins did not come with lids, but when a second set was purchased, the council made the decision to get lids with the bins as well. For those bins that lack a cover, we recommend that new lids be purchased and distributed. If the Tambon Council acquires more lids to at least accommodate these bins, it could prevent some of the litter problem in the tambon as well as reduce the number of disease vectors that access the bins.

5.3 Raise Community Awareness of Current Problems

Through our discussions with the Tambon Council, Khun Poonsin, and others, our team has concluded that the villagers of Sang Khom are either not cognizant of the short-term and long-term problems associated with the current waste disposal system, or they do not know what to do to help the situation. This lack of awareness was witnessed by the amount of litter on the roads and the non-existence of personal or community recycling and composting efforts. We agree with the Tambon Council that the villagers need to become aware of the problems associated with the current disposal system in order to take the required steps to reduce the current problems.

We propose two possible methods of educating the villagers about the need for change within the current waste disposal system. This education should raise community awareness of the pollution caused by the current dumping site and the need for participation in to help improve the system. This participation comes primarily in the form of personal waste reduction that decreases the amount of waste collected and disposed of at the dumping site. The specifics of these options are discussed in Section 5.5.

Another way the villagers can help improve the waste disposal system is to help prevent littering. The litter on the road sides can be dangerous in that it creates another way that disease vectors can spread illness. The villagers should commit to the minimization of roadside littering in order to prevent the possible spreading of disease. Our team identified community workshops and teacher training as two methods to raise awareness regarding these issues.

5.3.1 Community workshop

We recommend that a community-wide workshop be held in order to raise the awareness of adult members of Sang Khom's community about waste disposal. A Tambon Council member, or other respected member of the community, could run this workshop and answer questions from the attendees. The person who leads the workshop would need to become familiar with this report and the improvement plans established by the Tambon Council. The workshop could be held several times in the evenings in order to allow as many villagers as possible to participate.[127] The workshop should be used to answer any questions that the villagers may have concerning the alterations made to the current waste disposal system as well as begin educating them on personal waste reduction. Strategies that the villagers can adopt in order to improve the current waste disposal system should also be discussed in these workshops.

5.3.2 Train teachers of local schools

Khun Poonsin mentioned that the adults of rural Thailand are not easily convinced to make changes in their way of life and may not be an attentive audience for suggestions that require personal participation; sometimes, it can be very difficult to teach people, who have already been practicing their habits in waste disposal for many years, how to adopt new habits. Instead, it was suggested by Khun Poonsin and the Tambon Council that awareness of the current waste disposal problems should be taught to the students in the local primary and secondary schools. We suggest that the teachers at the school be briefed on the issues detailed in this proposal and, more specifically, on the issues raised previously in Section 5.3 and 5.5. The teachers could then discuss these issues with their students during class time and tell them what can be done to improve the current system. This information could be a valuable part of their education and should be shared during school time.

During the second meeting with the Tambon Council, the audience was enthusiastic about our proposal to disseminate information about waste disposal practices through the local schools. They believed that students would be able convince their parents to participate in personal waste reduction options more effectively than a community workshop. The council members all agreed that awareness should begin at the level of the family unit. A school program would therefore be an effective strategy to do this.

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[127] We recognize that most of Sang Khom's population is involved in farming as their livelihood. Day light hours may be more difficult for these people to come to a workshop at that time.

5.4 Recyclables collection and transportation

We have concluded that it is currently infeasible for the tambon to establish a recycling collection program because of the lack of a purchasing market. As mentioned in the background, artificial methods can be used to establish a market for recyclables, but this must be done at the central government level. It is unlikely that the government will establish such a system in the near future. If Sang Khom's costs were to be subsidized by the central government, we would suggest that a truck and three man crew be responsible for collecting bottles and other recyclables for shipment to a local buyer.

We recommend that the Tambon Council investigate the possibility of a recycling facility in Udon Thani that accepts metal, paper, and plastics. If a recycling facility were willing to accept recyclables from Sang Khom, and if the central government subsidized Sang Khom for the cost of collection and transportation of recyclables, we would recommend that the Tambon Council then start a municipally-run recyclables collection program. Perhaps new bins could be purchased and placed in densely populated areas to collect the villagers' recyclable waste. Villagers would bring recyclables to these bins, and the tambon's collection vehicle could collect and transport these recyclables to the facility in Udon Thani. The use of fewer bins to collect recyclables is more cost effective than curbside collection at every household.

As mentioned in our background chapter, buyers of recyclables are usually more willing to purchase from large areas than small ones. If the tambon of Sang Khom could combine with the other five tambons in the Sang Khom district, a buyer may be more willing to purchase recyclables at a higher price. This could make collection and shipment of glass bottles financially feasible for the tambon.

A community program to reuse wastes is a more economically feasible recycling option than shipping recyclables at the current time. Old and perhaps unneeded household items could be collected and stored, to be later picked up by other community members; this would be similar to the operation of the organization called the Salvation Army in the United States. This program could involve the collection of old appliances, clothes, or other items that can be reused with little or no processing. These items could then be kept at a vacant warehouse and villagers could come and pick up items of interest at no charge.

5.5 Promote Personal Waste Reduction

Our team has concluded that the only personal waste reduction option feasible for Sang Khom is backyard composting. By using the education methods of a community workshop and a school program, Sang Khom may be able to achieve a reasonable rate of participation in backyard composting once the methods are implemented. At our second meeting with the Tambon Council, the members were very enthusiastic about the possibility of backyard composting. During the meeting, Khun Wanidda Sreesangkom told the council that she would volunteer to share her knowledge of composting with the school that she teaches at or at the community workshop if the Tambon Council wished to promote backyard composting in Sang Khom. Khun Wanidda has been composting her organic waste for many years already, and she greatly wishes to see her community begin this practice because she understands the benefits through first-hand experience with the method.

To promote backyard composting, the villagers need to be educated about the amount of space being filled at the present dumping site by compostable organics. Also, the benefits of the natural fertilizer produced by composting, called humus, should be discussed. Considering that 90 percent of the population is involved in agriculture, a low-cost substitute for chemical fertilizers should be welcomed.[128] The health and environmental problems caused by the use of chemical fertilizers should be explained to the villagers as well.

Backyard composting could be accomplished with minimal equipment. A family's food waste and yard waste could be mixed and piled in a shaded area with or without enclosure. The pile should be kept moist and turned once every two days. Useable humus could be formed within 6 to 12 months. If animal manure or high-sugar molasses were mixed in with the compost, the process would be complete within one to two months, and the produced of humus would have a higher nutritional content for agricultural use. With Khun Wanidda's help, the villagers could successfully run there own composting heaps and use the humus to fertilize their gardens or farmland. If a large percentage of the community becomes involved in composting, the amount of waste being disposed of in a landfill will be drastically reduced.

5.6 Involve a Larger Area

Discussions with Senator Somkid Sreesangkom and Khun Poonsin indicated that funding might be more readily available if a larger population were included in this project. Because Sang Khom is less than 12 kilometers across at all points, a larger area could be encompassed, reaching the 30 kilometer distance proposed in the feasibility study for a large landfill in the province of Prachuap. This 30 kilometer distance was considered to be the most cost effective distance for collection and travel expenditures for the Prachuap province. Senator Somkid suggested that the district of Phen be considered for inclusion in this proposal because of its size and its proximity to the district of Sang Khom. The Tambon Council stated though that cooperation between the districts is unlikely.

The entire district of Sang Khom, containing six tambons including the tambon of Sang Khom, is an area that will (according to the Tambon Council) more likely facilitate the collection of waste to a central landfill. This district is no more than 22 kilometers wide at any point and has a population of over 28,000. Hua Hin, with a population of 40,000 people, received funds from the central government to build a sanitary landfill; it may be possible for the district of Sang Khom to receive similar funding. The Tambon Council agreed that a combined waste disposal project in the district of Sang Khom could be possible in the future.

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[128] Interview with Khun Poonsin Sreesangkom

5.7 Investigate Sources of Funding

Our team has done a limited search for funding of this project, but we have applied for funding through the British Community in Thailand Foundation. The entire proposal is found in Appendix M. As mentioned in the background, the proposed landfill in Prachuap received a 550 million Baht budget from the National Environmental Fund, which is an organization of the OEPP. We suggest that Senator Somkid Sreesangkom and the Tambon Council consider applying to this organization for funding. If the Tambon Council is the applicant for funds, we recommend that the proposal emphasize the motivation of the villagers to make and accept changes. The proposal should embrace a waste disposal system for the entire district of Sang Khom.

6. Conclusions

When our project team was initially approached by Senator Somkid Sreesangkom and Khun Francesca Sreesangkom to work on assessing the current waste disposal system in the tambon of Sang Khom, our first question to him was why he decided to sponsor such a project. During our time in Bangkok and in other locations in Thailand, we have noticed that there is a need for waste disposal improvements in many places. It seemed peculiar that Sang Khom, a very small rural group of villages, was selected for this project. Through talking with Senator Somkid, we discovered that he grew up in Sang Khom, and now, as a Senator in the Parliament of the Kingdom of Thailand, he represents this area. His position gives him the opportunities to give back to the village that helped him to become what he is today.

After talking with Senator Somkid and Khun Francesca, we were referred to a nephew of the senator's, Khun Poonsin Sreesangkom. Khun Poonsin also grew up in Sang Khom, eventually leaving home to go on to university and become an engineer. Later on in his life, he discovered that his interests lie more in the environment than in engineering, so he became part of the Global Environmental Fund/Small Grants Programme of the United Nations. Through working with this organization, Khun Poonsin has been given the opportunity to work with developing areas and help conserve the environment. Being a part of this organization has only increased his desire to see Sang Khom develop a waste disposal system that is not as harmful to the environment as the present system. He believes that the uncontrolled leachate could be contaminating nearby farmland and that the open-air incineration is hazardous to the villagers who live close to the site. In fact, the dumpsite that was being used prior to the current one was quite close to his residence in Sang Khom, as well as many other villagers' homes. He helped to make it known that the waste disposal site should be relocated at a distance farther away from the villages. Khun Poonsin, like Senator Somkid, knows that change is possible, and that it would be beneficial for the tambon to improve the waste disposal system.

Once we had visited the tambon of Sang Khom and seen the waste disposal system for ourselves, we understood the concerns that Senator Somkid and Khun Poonsin had with the system, though the tambon's waste disposal system is no worse than many other places in Thailand. Many rural areas of Thailand are being influenced by the commercialization and industrialization of the urban areas close to them; they are beginning to integrate items such as plastic packaging and synthetic materials into their lifestyles and into the community's waste stream. These materials are now being thrown away in the same manner as organic waste, which can be disposed easily because of their biodegradable nature. By burning the synthetic packaging materials along with food and yard waste, the air is being polluted with chemicals toxic to humans. This open-air incineration is also harmful to the environment, contributing to global warming, and is a health hazard, being a potential cause of respiratory illness.

While this commercialization could potentially cause the same problems in urban areas, more often than not, these areas have the funds to construct sanitary waste disposal systems. Rural areas as small as Sang Khom do not necessarily have a budget large enough to support an environmentally sound incinerator or even a sanitary landfill, and it is difficult for such a small area to acquire special funding for such a project. It was evident from our study that larger populations have more opportunities for acquiring funding from outside sources than smaller populations. This lack of funding for smaller villages puts these areas in a difficult position; even if some villagers realize that problems exist with the current disposal system, a limited budget prevents them from improving the system. It is unfortunate that areas similar to Sang Khom are not given the chance to improve their waste disposal systems simply because they do not have the funding to do so.

It seems as though Sang Khom's waste disposal problem is not only affecting its own villagers, but can potentially affect people in other countries, such as Laos. During the rainy season, leachate can run-off into surface water that is connected to the Huey Long Creek. This creek is a tributary of the Mekong River, which acts partially as the border between the country of the Kingdom of Thailand and the country of Laos. Thus, Sang Khom's problem is not only a local problem, but is part of a larger, international environmental concern. Therefore, it is crucial that the potential pollution of these international waters be prevented before it becomes more serious.

It is commendable that the Tambon Council has taken a strong interest in improving the waste disposal system of Sang Khom. When our team met with the council to learn what they believed was wrong with the system and what improvements they thought could be made, the council members spoke of the possibility of leachate contamination. They also believed that educating the villagers of the problems present in the current system, as well as informing them about how the problem can be solved, would be beneficial. The possibility of composting was brought up by various council members, and they believed that by showing the villagers how it can be beneficial, the villagers will be more willing to begin composting their organic wastes. Though in our proposal we offer many suggestions to make improvements, the Tambon Council need not attempt to implement all of the suggestions immediately. We realize how difficult some of our recommendations may sound due to the current lack of funding, but even implementing minor changes can help to improve Sang Khom's system. For instance, we believe that simply ceasing to burn the waste that is in the waste disposal site will decrease the amount of pollution being emitted into the air, and that the covering of the dumping site with soil on a daily basis will greatly alleviate the prominence of disease vectors. Any effort to implement minor recommendations similar to these will lessen the environmental hazards present in the current system.

We also think that it may be possible to have another WPI student project based in this particular area. One project might be to assess the success of Sang Khom's efforts to improve the current waste disposal system. It would be advisable to wait two to three years until beginning such a project, as implementing a program at the schools in the tambon may take one to two years for the villagers to get organized and commence the improvement process. Once the tambon has made changes to its waste disposal system, an assessment of what aspects of their methods of improvements worked and which ones did not may be a useful supplement to the project we have just completed. Using these two projects together could help another village to come up with a plan to improve its waste disposal system by learning how to assess a waste disposal system's effectiveness and safeness, and then seeing how another group of villages worked to improve any problems that were found.

Whether or not another IQP is created to go along with this particular project, it seems that the project that we have completed could be applied to other rural areas with a need for better waste disposal systems. In our methodology, we outlined the steps that we, as a team, took to complete our assessments. Assessing another village's current system could be done by obtaining a detailed physical description of the system and interviewing those involved in the management of the site. Assessing the feasibility of implementing a new system in another village could be done by comparing the cost-effectiveness, technical feasibility, and social and environmental implications of each system considered to be a possibility. It is our hope that this proposal will both be successful in keeping Sang Khom's environment clean and maintaining the villagers' health, as well as help other rural areas overcome the difficulties similar to those faced by Sang Khom.

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APPENDICES

Appendix A – Glossary of Acronyms

BCTFN	- The British Community in Thailand Foundation for the Needy
CBO	- Community Based Organizations
cm	- Centimeter
DEQP	- Department of Environmental Quality Promotion
EDF	- Education for Development Foundation
ESP	- Electrostatic Precipitator
EU	- European Union
GEF	- Global Environment Fund
HDPE	- High Density Polyethylene
I.D.	- Inside Diameter
kg	- Kilogram
km	- Kilometer
m	- Meter
mm	- Millimeter
MOSTE	- Ministry of Science, Technology, and Environment
MSW	- Municipal Solid Waste
NEF	- National Environmental Fund
NGO	- Non-governmental Organizations
NEQA	- Enhancement and Conservation of National Environmental Quality Act
PCD	- Pollution Control Department
PETP	- Polyethylene Terephthalate
PVC	- Polyvinyl Chloride
OEPP	- Office of Environmental Policy and Planning
SGP	- Small Grants Programme
UNDP	- United Nations Development Programme
U.S.	- United States
U.S. EPA	- United States Environmental Protection Agency
VOC	- Volatile Organic Compound

Appendix B-Sponsor Information

Letter from Khun Sreesangkom to Professor Weininger: (Saturday, September 8, 2001)

Dear Professor Weininger,

Thank you for your email. My husband and I look forward to meeting you in December.
He suggests that we limit the garbage disposal project to one tambon. T. Sang Khom has 12 villages with 1606 households and 7525 people. There is no commercial material - only household garbage and garbage from the village markets. At present the Tambon Council provides 2000 garbage containers, which cost B350 each. There is one truck, cost B400,000, with one driver and four helpers who are paid B4100 per month. They go every day to every village in the Tambon to empty the containers. The garbage is dumped in a pit five kilometers from Sang Khom and three k. from the nearest village.
The Council paid B300,000 for 16 rai of higher ground and a pit was dug 3 meters deep. Once a year the garbage is covered with earth. Budget. B2 million from local taxes and B1200,000 government subsidy per year. The old pit nearer Sang Khom village that I saw two years ago attracted flies and was smelly. That is why a bigger piece of ground was bought on higher ground.

Kind regards

Francesca Sreesangkom

Letter from Khun Sreesangkom to our team: (Wed. November 21, 2001)

Dear WPI team,

Thank you for your email. We look forward to meeting you.

Regarding your questions, the villagers complained among themselves mostly about the old waste disposal pit which has now been filled in. Since 1997 garbage has been disposed of at a new pit 4-5 kilometers from Sang Khom on the road to Ampur Phen. It is about 700 meters from the nearest village and I have been told that odor is not a problem now. The District Health Officer was Mr. Prasit Insuwor. A new Health Officer has recently been appointed and nobody I have asked seems to know his name. We will continue our enquiries. The pit is 20 by 30 m. and about 3 m. deep. In the dry season garbage is incinerated as much as possible. Over one ton of garbage is collected per day from 12 villages. There is one truck, 2 drivers and 2 workers. During the past months garbage collectors have been picking up things such as bottles and cans to sell. There does not appear to be evidence that the current method is a source of health hazards, though it seems likely. My husband does not think there are local statistics on villagers health but I will ask someone to make enquiries at the hospital in the area.

Sincerely,

Tessa Sreesangkom
for Senator Col. Somkid Sreesangkom

Appendix C-Information on Organizations Connected with the Project

C.1 Taunton Landfill

Contact Information:

Denis Hammon. 508-821-4444.

General Information: Handles 120,420 tons annually and it is 13 percent MSW

C2. Crapo Hill Landfill

Contact Information:

Hank Van Larrhoven. 508-988-5674.

General Information: Dumps 115,000 tons annually, and it is 100 percent MSW

C3. Thai Department of Mineral Resources

Official Information: See page #C.3.1

C4. Worcester Sanitation department

Contact information:

Picard, Joseph. 508-799-1495.

C.5 Worcester Dept of Health and Code

Contact information:

David Crocker. 508-799-8534.

C.6 SCAT Engineering

Contact information:

http://www.scat.com.
E-mail: sales@scat.com.
Tel: 800-843-7228.

C.7 Commonwealth of Massachusetts Executive Offices of Environmental Affairs: Department of Environmental Protection.

Contact information:

http://www.state.ma.us/dep

C.8 Department of Environmental Quality Promotion

Contact information:

http://www.deqp.go.th/english/index.html
60/1 Soi Phibunwattana 7
Rama VI Road, Phayathai, Bangkok 10400.
Tel: 662-2986020-9
Fax: 2986032
E-mail address: info@deqp.go.th

C.9 Arthur Andersen Business Advisory Ltd., Andersen Legal & Tax Ltd., and SGV-Na Thalang & Co., Ltd.

Contact Information:

http://www.aathai.com
20th - 23rd Floors, Siam Tower
989 Rama I Road
Pathumwan, Bangkok 10330

Tel: 66-2658-0611 | 0-2658-5000
Fax: 66-2658-0660-3

C.10 International Rivers Network

Contact Information:

http://www.irn.org
1847 Berkeley Way
Berkeley, CA 94703 USA
Tel: 510-848-1155
Fax: 510-848-1008
E-mail: irn@irn.org

C.11 Lexmundi

Contact Information:

http://www.lexmundi.org
2100 West Loop South, Suite 1000
Houston, Texas 77027 USA
Tel: 713-626 9393
Fax: 713-626 9933
E-mail: lexmundi@lexmundi.org

C.12 The Research Institute for Asia and the Pacific

Contact Information:

http://www.riap.usyd.edu.au/
Level 2, Services Building
353 Abercrombie Street (corner Codrington Street)
Darlington, Sydney
Tel: 61-2-9351-8547
Fax: 61-2-9351-8562
E-mail : postmaster@riap.usyd.edu.au

C.13 United Nations Economic and Social Commission for Asia and the Pacific

Contact Information:

http://www.unescap.org
The United Nations Building
Rajadamnern Nok Avenue
Bangkok, Thailand 10200
Tel: 66-2-288-1234
Fax: 66-2-288-1000
E-mail: webmaster@unescap.org

Appendix D-Thai Demographics

Population:	61,797,751 *note:* estimates for this country explicitly take into account the effects of excess mortality due to AIDS; this can result in lower life expectancy, higher infant mortality and death rates, lower population and growth rates, and changes in the distribution of population by age and sex than would otherwise be expected (July 2001 est.)
Age structure:	*0-14 years:* 23.43% (male 7,380,273; female 7,099,506) *15-64 years:* 69.95% (male 21,304,051; female 21,921,383) *65 years and over:* 6.62% (male 1,796,325; female 2,296,213) (2001 est.)
Population growth rate:	0.91% (2001 est.)
Birth rate:	16.63 births/1,000 population (2001 est.)
Death rate:	7.54 deaths/1,000 population (2001 est.)
Net migration rate:	0 migrant(s)/1,000 population (2001 est.)
Sex ratio:	*At birth:* 1.05 male(s)/female *Under 15 years:* 1.04 male(s)/female *15-64 years:* 0.97 male(s)/female *65 years and over:* 0.78 male(s)/female *Total population:* 0.97 male(s)/female (2001 est.)
Infant mortality rate:	30.49 deaths/1,000 live births (2001 est.)
Life expectancy at birth:	*Total population:* 68.86 years *Male:* 65.64 years *Female:* 72.24 years (2001 est.)
Total fertility rate:	1.87 children born/woman (2001 est.)
Ethnic groups:	Thai 75%, Chinese 14%, other 11%
Religions:	Buddhism 95%, Muslim 3.8%, Christianity 0.5%, Hinduism 0.1%, other 0.6% (1991)
Languages:	Thai, English (secondary language of the elite), ethnic and regional dialects

Literacy:	*Definition:* age 15 and over can read and write
	Total population: 93.8%
	Male: 96%
	Female: 91.6% (1995 est.)

Appendix E-Maximum Permissible Concentration of Drinking Water Constituents[129]

Constituent	Max. permissible concentration
	µg/L
Chloride	250,000
Copper	1,000
Hydrogen Sulfide	50
Iron	300
Manganese	50
Sodium	200,000
Sulfate	250,000
Zinc	5,000
Acetone	1,000
Phenols	2
Toluene	24
Antimony	10
Arsenic	50
Barium	1,000
Boron	5,000
Cadmium	5
Chromium VI	50
Selenium	10
Lead	10
Mercury	1
Nitrate as nitrogen	10,000
Silver	50
Cyanide	100
DDT	30
Endrine	.2
Lindane	4
Methoxychlor	100
Toxaphene	2
2,4-D	1,000
2,4,5-TP silvex	10
Synthetic Detergents	500
1,2-Dichloroethene	70
1,2-Dicholoenthane	5
1,4-Dicholorbenzene	5
1,4-Diozane	4.12
Dichloromethane	50
Tetrachloroethylene	500

[129] R. Kerry Rowe. Clayey Barrier Systems for Waste Disposal Facilities. p. 46.

Trichloroethylene	50
Trichloromethane	100
Xylenes	300
Vinyl Chloride	2

Appendix F-The Eight Fold Path

Wise View: Wise View is the integrated understanding of The Four Noble Truths.

Wise Intention: Wise Intention is the intention of harmlessness, good will, non–greed, simplicity and non–distractedness in every thought, word and deed.

Wise Speech: Wise Speech is speech that originates in mindful presence; speech that is not false, slanderous or harsh; speech that avoids useless chatter and gossip.

Wise Action: Wise Action is action that preserves and does not destroy life; action that takes only what is freely given; action that does not steal; sexual action that originates in kindness and respect and avoids sexual transgressions.

Wise Livelihood: Wise Livelihood is earning one's living by adhering to the Precepts.

Wise Efforts: Wise Effort is effort that develops and maintains mindfulness

Wise Mindfulness: Wise Mindfulness is present–time awareness; awareness of the present moment; noticing the body and breath, feelings, thoughts, and mind states.

Wise Concentration: Wise Concentration is one–pointedness of mind. [130]

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[130] Buddhism 101.

Appendix G-Sample Interview Forms

G.1 Interview with tambon waste disposal manager

1) What is the capacity of the 200 collection bins?
2) What material are these bins made of?
3) Do these bins have covers?
4) Is waste collected daily?
5) How many men make up the collection crew?
6) What is the function of each man?
7) How long does the collection process take?
8) What is the cost of labor?
9) What is the cost of equipment currently used?
10) What is the capacity of the truck being used?
11) What is the per capita waste disposal rate in the tambon?
12) What is the general composition of the garbage in terms of constituents detailed in Table 2 above?
13) Where is the waste disposal pit located?
14) What is the depth of this pit?
15) Is the pit covered daily with soil or some other kind of liner?
16) Is there a basal liner in the pit?
17) Is there any gas ventilation for the pit?
18) Where is the water table in relation to the pit?
19) Where does the incineration take place?
20) Can you describe the incineration process?
21) Where is the residue from incineration disposed?
22) Which direction does the plume travel?

G.2 Interview with local tambon officials

1) Are there any specific problems with the 2 current methods of waste disposal that they believe calls for some kind of change? i.e. aesthetics or sanitary problems?
2) What is the population of the tambon?
3) What is the population growth rate of the tambon?
4) How much waste is disposed per day in the tambon?
5) Are there any maps (general/topographical) of the area which show the relation of the pit, the village, and the incineration site?

6) Are you worried about the air pollution that is a result of open air incineration?
7) Are you concerned that the smoke and ash from this incineration could cause health problems with the villagers such as lung cancer?
8) What months can the waste be incinerated?
9) What is the price of land used for the pit?
10) Who did you buy the land from?
11) Where does the funding come from to pay for the garbage disposal?
12) What is yearly budget for waste disposal?
13) How much did the truck cost?
14) How much does it cost to rent a bull dozer for earth excavation?
15) Is there any surplus in the tambon's budget for projects to improve current system of waste disposal?
16) Is there a concern of dogs, rats, insects and birds getting into the pit or bins, and then possibly spreading disease?
17) Are you concerned that run off from the waste could reach the reservoir and contaminate fish, and rice paddies?
18) Do you believe that the daily collection is reliable?
19) Do you have any information about rainfall or any rainfall statistics?
20) Are there any prevailing wind patterns around the current pit location?
21) What are your opinions about: sanitary landfill, environmentally sound incinerator, tambon-wide composting, backyard composting, recycling, and combinations of those?
22) How do you think we should educate villagers about the problems with current method, waste reduction, and introducing composting?
23) What do you think about a community workshop, a school program for composting, pamphlets, or newspaper as a means for education?
24) If we proposed something that exceeds the current budget for waste disposal, do you think the tambon will be willing to accept a tax raise?
25) Would there be any restrictions as to where we could propose to place a land filling site?

G.3 Interview with Poonsin Sreesangkom

1) Do you have any geohydrological or topographical maps?
2) Where can we obtain information about weather patterns and rainfall statistics?
3) In general, what are your feelings about the pit?
4) What are your opinions about: sanitary landfill, environmentally sound incinerator, tambon-wide composting, backyard composting, recycling, and combinations of those?

5) Are there any other specific problems with the 2 current methods of waste disposal that they believe calls for some kind of change? i.e. aesthetics or sanitary problems?
6) What is your opinion about daily collection? Would weekly or bi-weekly be better?
7) What is the best way to educate the villagers in regards to separation of waste?
8) How would we contact waste disposal experts for land filling and composting information?
9) What is the population growth rate of the tambon?
10) Have you contacted any companies to inquire about incineration?
11) Are there any scavengers of the waste? What do they scavenge? What do they do with it?
12) Where is the closest recycling facility, and what do they recycle?
13) What are your expectations for this project?
14) Are there any environmentally sound incinerators in use in Thailand/Bangkok?

G.4 Interview with retired district health officer

1) Have you found any evidence of breathing difficulties in villagers of T. Sang Khom that could be related to smoke and ash inhalation from open-air incineration?
2) Have you seen an uncommonly high number of cases of gastroenteritis, dysentery, hepatitis, and encephalitis? (with respect to other tambons that do not dispose of their waste in such a fashion, or the disposal takes place father away)
3) Do you believe that the current pit/incineration method is unsanitary in general? If so, why?

G.5 Interview with Steven Sibinich of the Millbury Wheelabrator (Incineration with energy recovery)

Contact info (508)-791-8900

1) How much waste does it handle per day?

1500 tons/day

2) What are moisture content requirements?

No restrictions

3) When was it constructed, and how much did it cost?

1987 at $130 million

4) What system do you use to collect ash particles (filter, or electrostatic precipitator)?

They are using electrostatic precipitator, and will be putting in a fabric filter bag house soon to replace the precipitator

5) What do you use to scrub for acidic components i.e. SO_x, HCl.?

Quick lime is atomized and sprayed into the scrubber to neutralize Sox, HCl

6) How to you control NO_x

Thermal De-NO_x sprays urea into scrubber to control NO_x

7) How do you aerate the burning stuff to get excess O2 in there to prevent CO formation?

Did not ask this question.

G.6 Interviews with Massachusetts landfill operators

1) What type of equipment is used to dump garbage, shred garbage, compact garbage, and excavate earth.
2) What does each piece of equipment cost?
3) What is the cost of crucial daily operations and eminence
4) What are examples of these crucial operations? I.E. fuel. For trucks?
5) Do they use any synthetic basal liner? If yes, ask what material was used, and how much it cost
6) How do they collect leachate and vent gases. What kinds of pipes are used, and what special equipment is used?
7) Do they have any knowledge about the sites hydrogeology? Like what is underneath the site (clay, silt, sandstone?) How far down is the aquifer?

Appendix H - Handout used at Presentation to Tambon Council

I. Problems with the Current Waste Disposal System
   i. Pollution of Local Water
      1. Local Reservoirs (Fishing Water, Farmlands)
      2. Ground Water
   ii. Pollution from Open-Air Incineration at Dumpsite
   iii. Disease Transmitting Animals
      1. Access to Open Bins
      2. Access to Open Dumping Site
II. Steps for Improvement
   i. Improve the Current Dumpsite
      1. Create Leachate (Waste Water) Drainage System
      2. Cover Exposed Wastes with Soil Daily
      3. End Open-Air Incineration
   ii. Improve Waste Collection
      1. Purchase Larger Collection Vehicle
      2. Hirer Two More Laborers
      3. Require Covers for Waste Bins
   iii. Educate Villagers about Current Problems
      1. Hold Community Workshop
      2. Educate the Youth Through School Programs
   iv. Waste Reducation Options
      1. Backyard Composting
      2. Volume Based Fees
      3. Community Recycling
   v. Study Examples of Hua Hin and Prachuap
   vi. Include Larger Area (tambon of Phen) to Acquire More Funds
   vii. Possible Sources of Funding
      1. The British Community in Thailand Foundation for the Needy
      2. National Environmental Fund
      3. Education for Development Fund
      4. Global Environmental Fund/Small Grant Program of Thailand
III. Future Considerations

i. Construct New Engineered Landfill

    1. Consider Topography and Water Table Levels
    2. Consider Size of Landfill
    3. Analyze Weather Pattern
    4. Create Gas Ventilation
    5. Create Better Access Roads

ii. Sell Recyclables

    1. Initiate Curbside Collection
    2. Combine Recyclables with Larger Area
    3. Find Available Market

Appendix I – Observations in Tambon Sang Khom

Waste bins: Take pictures and note materials of construction. Determine capacity of bins. Note odor of bins, and any foreign beings living in, or around, the receptacle.

Composition of waste: With gloves, pick apart garbage. Note composition with regards to Table 2.

Dumping site: Take pictures of site. Note odor from pit, and any animals living in the near by vicinity. Collect leachate sample for testing.

Take a sample of drinking water from main well

Incineration site: Take pictures and note air quality.

Truck: Take pictures and measure the capacity of the truck.

Appendix J – Drinking Water Quality Standards

Drinking Water Quality Standards[131]

Properties	Parameters	Units	Standards	
			Maximum Acceptable	Maximum Allowable
Physical	Color	Pt-Co	5	15
	Taste	-	non objectionable	non objectionable
	Odor	-	non objectionable	non objectionable
	Turbidity	SSU	5	20
	pH	-	6.5-8.5	9.2
Chemical	Total Solids	mg/dm^3	500	1.500
	Iron (Fe)	mg/dm^3	0.5	1.0
	Manganese (Mn)	mg/dm^3	0.3	0.5
	Fe & Mn	mg/dm^3	0.5	1.0
	Copper (cu)	mg/dm^3	1.0	1.5
	Zinc (Zn)	mg/dm^3	5.0	15.0
	Calcium (Ca)	mg/dm^3	75^b	200
	Magnesium (Mg)	mg/dm^3	50	150
	Sulphate (SO_4)	mg/dm^3	200	250^c
	Chloride (Cl)	mg/dm^3	250	600
	Fluoride (F)	mg/dm^3	0.7	1.0
	Nitrate (NO_3)	mg/dm^3	45	45
	Alkylbenzyl	mg/dm^3	0.5	1.0
	Phenolic substance	mg/dm^3	0.001	0.002
Toxic elements	Mercury (Hg)	mg/dm^3	0.002	-
	Lead (Pb)	mg/dm^3	0.05	-
	Arsenic (As)	mg/dm^3	0.05	-
	Selenium (Se)	mg/dm^3	0.01	-
	Chromium	mg/dm^3	0.05	-
	Cyanide (CN)	mg/dm^3	0.2	-
	Cadmium (Cd)	mg/dm^3	0.01	-
	Barium (Ba)	mg/dm^3	1.0	-
Bacterial	Standard plate	$colonies/cm^3$	500	-
	Total coliform	$MPN/100cm^3$	2.2	-
	E.Coli	$MPN/100cm^3$	*None*	-

[131] http://www.pcd.go.th. Date: January 15, 2002.

Ground Water Quality Standards for Drinking Purposes:[132]

Properties	Parameters	Units	Standards	
			Suitable	Maximum
Physical	Color	Pt-Co	5	15
	Turbidity	JTU	5	20
	pH	-	7.0-8.5	6.5-9.2
Chemical	Iron (Fe)	mg/l	0.5	1.0
	Manganese (Mn)	mg/l	0.3	0.5
	Copper (cu)	mg/l	1.0	1.5
	Zinc (Zn)	mg/l	5.0	15.0
	Sulphate (SO_4)	mg/l	200	250
	Chloride (Cl)	mg/l	250	600
	Fluoride (F)	mg/l	0.7	1.0
	Nitrate (NO_3)	mg/l	45	45
	Total hardness as	mg/l	300	500
	Non-Carbonate	mg/l	200	250
	Total solids	mg/l	600	1.200
Toxic elements	Arsenic (As)	mg/l	*None*	0.05
	Cyanide (CN)	mg/l	*None*	0.1
	Lead (Pb)	mg/l	*None*	0.05
	Mercury (Hg)	mg/l	*None*	0.001
	Cadmium (Cd)	mg/l	*None*	0.001
	Selenium (Se)	mg/l	*None*	0.01
Bacterial	Standard plate	colonies/ml	500	-
	Coliform bacteria	MPN/100ml	2.2	-
	E.Coli	-	*None*	-

[132] *Idem*

Surface Water Quality Standards[133]:

Note that:

Class 1 refers to "extra clean" fresh surface water resources used for:

1) conservation not necessary pass through water treatment process require only ordinary process for pathogenic destruction.
2) Ecosystem conservation where basic organisms can breed naturally

Class 2 refers to "very clean" fresh surface water resources used for:

1) consumption which requires ordinary water treatment process before use
2) aquatic organism of conservation
3) fisheries
4) recreation

Class 3 refers to "medium clean" fresh surface water resources used for:

2) consumption, but passing through an ordinary treatment process before using
3) agriculture

Class 4 refers to "fairly clean" fresh surface water resources used for:

1) consumption, but requires special water treatment process before using
2) industry

Class 5 refers to "The sources which are not classification in class 1-4 and used for navigation"

Surface Water Quality Standards

Parameter	Units	Statistics	Standard Value for Class					Methods for Examination
			Class 1	Class 2	Class 3	Class 4	Class 5	
1. Color. odor.	-	-	n	n	n	n	-	-
2. Temperature	C°	-	n'	n'	n'	n'	-	Thermometer
3. pH	-	-	n	5-9	5-9	5-9	-	Electrometric pH
4. Dissolved	mg/l	P20	n	6	4	2	-	Azide
5. BOD (5 days.	mg/l	P80	n	1.5	2.0	4.0	-	Azide
6. Coliform bacteria								Multiple Fermentation Technique
- Total coliform	MPN/100	P80	n	5.000	20.000	-	-	
- Fecal coliform	MPN/100	P80	n	1.000	4.000	-	-	
7. NO_3 -N	mg/l	Max.	n	0.5			-	Cadmium

[133] Idem.

8. NH_3-N	mg/l	-	n	0.5	-	Distillation
9. Phenols	mg/l	-	n	0.005	-	Distillation.4-
10. Copper (Cu)	mg/l	-	n	0.1	-	Atomic
11. Nickel (Ni)	mg/l	-	n	0.1	-	Atomic
12. Manganese	mg/l	-	n	1.0	-	Atomic
13. Zinc (Zn)	mg/l	-	n	1.0	-	Atomic
14. Cadmium (Cd)	mg/l	-	n	0.005*	-	Atomic
15. Chromium	mg/l	-	n	0.05	-	Atomic
16. Lead (Pb)	mg/l	-	n	0.05	-	Atomic
17. Total Mercury	mg/l	-	n	0.002	-	Atomic
18. Arsenic (As)	mg/l	-	n	0.01	-	Atomic
19. Cyanide (CN)	mg/l	-	n	0.005	-	Pyridine-
20. Radioactivity						Low Background
21.Total	mg/l	-	n	0.05	-	Gas-
22. DDT	ug/l	-	n	1.0	-	Gas-
23. Alpha-BHC	ug/l	-	n	0.02	-	Gas-
24. Dieldrin	ug/l	-	n	0.1	-	Gas-
25. Aldrin	ug/l	-	n	0.1	-	Gas-
26. Heptachlor &	ug/l	-	n	0.2	-	Gas-
27. Endrin	ug/l	-	n	none	-	Gas-

Remark :

P	Percentile value
n	naturally
n'	naturally but changing not more than 3 °C
*	when water hardness not more than 100 mg/l as $CaCO_3$
**	when water hardness more than 100 mg/l as $CaCO_3$
Based on	Standard Methods for the Examination of Water and Wastewater recommended by APHA : American Public Health Association, AWWA : American Water Works Association and WPCF : Water Pollution Control Federation

Appendix K - Details of the Loei River Conservation Project

Location: Erawan Sub-District, Loei Province

Objective: Protect Loei river by instilling conservation awareness

The tangible activities of this project did meet the above object. Through the promotion of backyard composting, the project raised awareness of problems caused by improper solid waste disposal. The GEF / SGP began composting projects at the central school in 4 neighboring villages. It was the hope of the GEF / SGP to raise awareness in the students and have them discuss waste disposal issues with their parents. It was further hoped that families would begin composting at home to meet the goals listed in background section 2.4.4.

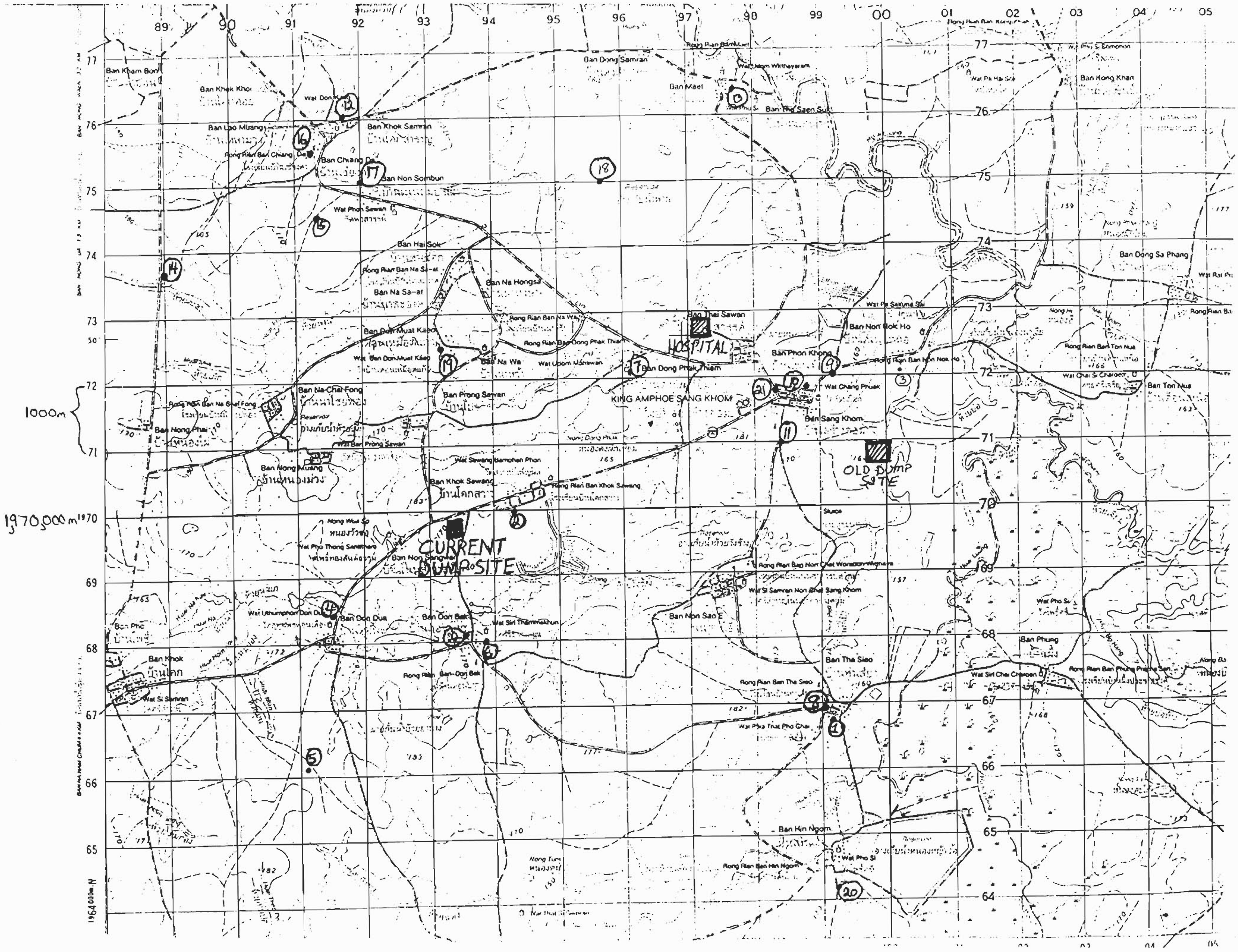
To complete this project, the Ministry of education provided 40 to 50 square meter plots of land at the schools for use by the GEF / SGP personnel. Each plot contained a classroom type area for instruction, an area for sorting garbage to remove non compostables, and a composting pile area. Each of the four schools collected 60 Kg / day of lunch waste and 500 Kg of agricultural wastes brought from home during a 3 month period. Molasses was added to the compost to hasten the process. The humus produced at the end of the process was used to help grow 20 kg / school / day of 100% organic produce. The schools each saved 2500 Baht per semester in costs normally spend on chemical fertilizer. Water that settled at the base of the compost pile was also used for a starting substance of dish washing solution, shampoo, and detergent. This leachate could also be

The project had great impact in Thailand. The schools were visited by 215 farmers, and over 70 government officials who were interested in this project. The farmers were interested in using composting to produce natural fertilizer while the government officials were interested in starting similar projects elsewhere.

The budget for the project was 355,800 Baht. 273,000 Baht came from the GEF / SGP. The tambon council provided 3,000 Baht. The schools provided 2,000 Baht, and the communities raised 77,800. Baht.

Appendix L – Topographical Map of Area

See Attached Sheet



CURRENT DUMP SITE
OLD DUMP SITE
HOSPITAL
1000m
1970,000m
1964000m.N
KING AMPHOE SANG KHOM
Ban Sang Khom
Ban Thai Sawan
Ban Dong Phak Thiem
Ban Phon Khong
Ban Non Nok Ho
Wat Pa Sakuna Siri
Wat Chang Phuak
Ban Ton Nua
Ban Dong Sa Phang
Ban Kong Khan
Ban Dong Samran
Ban Mael
Wat Udom Witthayaram
Ban Kham Bon
Ban Khok Khoi
Wat Don Kloi
Ban Loo Muang
Ban Khok Samran
Ban Chiang Da
Ban Non Sombun
Wat Phon Sawan
Ban Hai Sok
Rong Rian Ban Na Sa-at
Ban Na Sa-at
Ban Na Hongsa
Ban Don Muat Kaeo
Wat Ban Don Muat Kaeo
Ban Na Wa
Rong Rian Ban Na Wa
Rong Rian Ban Dong Phak Thiam
Wat Udom Mahawan
Ban Prong Sawan
Ban Na Chai Fong
Rong Rian Ban Na Chai Fong
Reservoir
Ban Nong Phai
Wat Ban Prong Sawan
Ban Nong Muang
Wat Sawang Samphan Phon
Ban Khok Sawang
Rong Rian Ban Khok Sawang
Nong Wua So
Wat Pho Thong Santitham
Ban Non Sangwan
Wat Uthumphon Don Dua
Ban Don Dua
Ban Pho
Ban Khok
Wat Si Samran
Ban Don Bak
Wat Siri Thammakhun
Rong Rian Ban Don Bak
Ban Non Sao E
Wat Si Samran Non Chat Sang Khom
Rong Rian Ban Non Chat Worasan Wignara
Sluice
Ban Tha Sieo
Rong Rian Ban Tha Sieo
Wat Phra That Pho Chai
Wat Siri Chai Charoen
Ban Phung
Wat Pho Si
Ban Hin Ngom
Rong Rian Ban Hin Ngom
Wat Pho Si
Nong Tum
Wat Chai Si Charoen
Rong Rian Ban Ton Nua
Rong Rian Ban Non Nok Ho
Wat Pa Hai Sok
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Appendix M – Proposal to BCTFN

B.C.T.F.N

The British Community in Thailand Foundation

For the Needy

(Under the auspices of the British Embassy – Bangkok)

Tel: 204 1587 591/17

Sukhumvit Road

Fax: 204 1589

Soi Villa

Bangkok 10110

E-Mail: bctfn@loxinfo.co.th

APPLICATION FOR FUNDING

Date: January 21st, 2002

Project Title:

Solid Waste Disposal in Tambon Sang Khom

Recipient Organization

Tambon Council. Obitors of Tambon

Name of person applying for assistance

Senator Somkid Sreesangkom & Khun Francesca Tessa Sreesangkom

Present position in Thailand

Member of Thai Senate and Chairman of the Education for Development Foundation..

Location of Project

Tambon Sang Khom in the Province of Udon Thani, Thailand

....

....

Contact Address

Khun Francesca Tessa Sreesangkom

23/56 Panpuying Pahon

Ngamwongwan Road

Bankok, Thailand 10900

Senator Somkid Sreesangkom's day time phone: 01 866 0636

Evening phone: 02 561 2989

Fax: 02 561 2989

E.Mail: dastella@cscoms.com

Project Objectives

1) Relocate and redesign landfill to protect local population and environment.
2) Improve efficiency of solid waste collection.
3) Minimize the waste disposed in the landfill though promotion of backyard composting.
4) Minimize the waste disposed in landfill through the promotion of organized collection of recyclables and shipment to nearby recycling facilities in Udon Thani.
5) Involve a larger area in this proposal. Phen is a likely candidate.
6) Raise awareness concerning environmental and health problems due to unsanitary waste disposal.

Project Description (include background, beneficiaries and timescale of Project) – please continue on a separate page if necessary:

Please see final page

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Details of assistance required (please attach any estimates):

1) (Not applicable for BCTFN) Funds for purchase of a used dozer-crawler, or donation of used dozer-crawler to the tambon. Used dozer-crawlers cost between 40,000 to 80,000 U.S. dollars. (1.76 to 3.52 million baht).
2) (Not applicable for BCTFN) Funds for purchase of used 14m^3 capacity highway style dump truck. This truck will cost between 30,000 and 50,000 U.S. dollars. (1.32 and 2.2 million baht).
3) Funds to support additional laborers. The current truck driver and the 3 collectors earn ~5000 baht per month. Three more laborers may be needed to manage the recycling collection and shipment. One additional laborer is needed to maintain the landfill site with the dozer-crawler. Five laborers at 5000 baht per month comes to 300,000 baht per year. This is about 6,820 U.S. dollars per year.

4) Funds to purchase PVC piping for leachate drainage and collection. This should cost 500 U.S. dollars. (22,000 baht)
5) Funds to purchase 200-400 recyclables bins. The cost to fabric new bins like the ones used for the current disposal is 150 baht per bin. 300 bins would cost 45,000 baht, equivalent to 1000 U.S. dollars.

The total of applicable requests from items 3,4, and 5 are 367,000 baht, or 8,350 U.S. dollars.

Breakdown of above costs if not already given:

See above...

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	Yes		No	
Are the beneficiaries Thai:		X		....
Is the project sustainable:		X		....
Is the organization registered in Thailand:		X		....
Does it have Foundation status:		....		X
Does it rely on fund raising:		X		....
Does it have capital earning interest		....		X

Who will pay when our support has ended?

The financial burden will be placed upon the villagers through taxation. Government grants may also be acquired.

Who would support if we don't:

It is uncertain at the moment if the central Thai government will support this project. The Thai GEF Small Grants Programme of the UNDP will be solicited for funds. Other international charities will also be solicited for funds.

Who will support next year:

As mentioned above.

Additional information:

This project has international environmental implications considering that the current waste disposal method pollutes the air through open-air incineration, and pollutes international waters because the leachate drains into a creek that feeds into the Mekong river on the border of Thailand and Laos.

If this project succeeds it may encourage other village communities in Thailand, which are disposing their wastes in a similar unsanitary fashion, to promote environmental awareness. It may also create an effort by the villagers to protect the local environment through activities such as back-yard composting and central recycling. This project could encourage the central Thai government to promote similar projects throughout Thailand and to financially support them.

A final report containing the assessment of waste disposal in the tambon, and a proposal for an economically feasible and environmentally sound waste disposal system should be completed by March 2nd, 2002. This report will be submitted to the BCTFN funding committee upon request.

Project Approved:

Date of Minutes:

Convenor:

Background to Solid Waste Disposal Project in the Tambon of Sang Khom:

Through observation and interviews with officials/laborers connected to waste collection and disposal in the tambon, it has been concluded that the current waste management practices are unsanitary and a threat to the local environment and health of the local population.

The solid waste in question originates from the tambon households, markets, small shops, and the local hospital. The hospital wastes are separated into bio-hazardous wastes and common wastes. The common wastes are collected and disposed along with the solid wastes of the households, markets and shops. The bio-hazardous wastes are incinerated onsite and the ash is disposed of in an open pit near the incinerator. The hospital's incinerator does not meet U.S.E.P.A. emissions regulations, but the cost of an environmentally sound incinerator is beyond feasible means of acquisition at this time, and is not part of this request for funding. Commercial and industrial wastes are not found in the tambon's waste stream.

The funding requested is required to meet the four objectives above with respect to the tambon's municipal solid waste. In regards to the first objective, the current disposal methods are considered to be unsanitary by all those interviewed: Senator Somkid Sreesangkom, Poonsin Sreesangkom (National Coordinator of The Global Environmental Fund Small Grants Programme in Thailand), the Tambon Council, and various community members. The current disposal method consists of open dumping of municipal solid waste and open-air incineration of this waste during the dry season. Pictures of the dumping site, taken in January 2002, are included below:

Sang Khom's open waste disposal site. Waste is currently being burned.

View of Sang Khom's waste disposal site from access road. The leachate drains into ditch to the left of the road.

This dumping site has no engineered leachate collection/treatment controls. During the rainy season the leachate and runoff drain into nearby farmlands and fishing waters 1 kilometer from the site. The site is covered by earth once or twice a year. The lack of daily earth coverage allows for insects and other disease vectors to breed and live in the waste disposal site. Local villagers have noticed an increase in population of a certain species of fly since the establishment of this dumping site three years ago. The open air incineration undoubtedly emits toxic dioxins, carbon monoxide, and carcinogenic particulate matter into the air. In order to minimize disease vector access to the pit, to minimize the flow of leachate to fishing waters and farming lands, and to prevent open air incineration, the dumping site must be re-designed or relocated. As part of the re-design, a dozer-crawler is needed to properly landscape the site to allow leachate and runoff to drain into a specified and contained collection area. This tractor-crawler will also be used to cover the waste daily with 6 to 12inches of earth. The tambon does not have easy access to a dozer-crawler and must rent it from an offsite location for limited periods of time. For this reason, it has been impossible for the tambon to maintain a more sanitary landfill. If the site is relocated, an area of land that is less likely to allow leachate to drain into fishing/farming waters must be selected and excavated with a dozer-crawler. The cost of purchasing a used dozer crawler is most likely beyond the budget of the BCTFN. As part of the redesign or relocation, perforated PVC piping must be installed at the base of the dumping site to allow the leachate to drain into an engineered collection site. The cost of these pipes should be within the budget of the BCTFN.

As part of the second objective, it has been concluded that the current collection of municipal solid waste is inefficient. The tambon, with a population of over 8000 people, has only 1 small truck designated for waste pickup. The truck's dimensions are 3.6 m by 1.7 m by 1.0 m. This allows for a capacity of only $6.2m^3$. Standard solid waste collection trucks have capacities of $14\text{-}18m^3$. One driver and three collectors ride with the truck daily to pick up waste from hundreds of rubber bins kept by families, shops, and markets. Interviews with the driver and villagers made it clear that waste was not reliably picked up. The driver noted that the truck broke down often, and the villagers mentioned that solid waste could be left out for days without pickup. Through observation, it was noted that a great deal of solid waste remains uncollected along many major roads in the tambon. It is concluded that an additional larger truck and funding for a larger crew is needed to make collection more reliable, and to clean up the streets. The cost of purchasing a used dozer crawler is most likely beyond the budget of the BCTFN.

As part of the third objective, it has been theorized that back-yard composting is an environmentally sound alternative to land filling. Approximately 60% of the tambon's municipal solid waste consists of food scraps, and compostable yard wastes. If there is a high participation rate the amount of waste land filled should decrease dramatically. To instigate back-yard composting a proposal will be brought to the tambon council to instigate a school program in which the teachers instruct the students on the benefits, and methods used in composting. It is hoped that the students will be able to talk to their parents and start family compost heaps. A community workshop will also be proposed to instruct elder community members of the benefits and methods of back-yard composting. In a previous study produced by Thailand's Global Environmental Fund/Small Grants Programme a similar school program was successful in establishing a reasonable family participation rate.

As part of the final objective, it has been concluded that a significant portion of the tambon's solid waste is recyclable. It was observed at the dumping site that most of the waste consisted of metal (aluminum, and steel) cans, and glass bottles. To further reduce the volume of waste disposed of in the landfill, it will be proposed to the tambon council that it be mandated for all families to separate recyclable glass, metal, and plastics from their normal wastes. These recyclables would then be collected and shipped to the nearest recycling facility. If a new truck is acquired for land filling dumping, the old truck could be used for the collection and shipment of recyclables. The tambon does not currently participate in this recycling scheme because the market for recyclables has dropped. The tambon losses money in collection and shipment of recyclables. If a high participation rate can be achieved among the villagers, the forth proposed objective could be met if funds for the following were obtained.

1) To pay extra laborers to collect the recyclables.
2) To pay truck petrol costs in the shipment of materials to the nearest recycling facility.
3) To pay for 200-400 community bins to keep recyclables separate from solid waste to be disposed of in the landfill.

Project Beneficiaries:

The beneficiaries of this project are the tambon villagers. This project helps to protect the local environment and the health of the villagers. Villager's fears of fishing waters and farm land being contamination, and fears of flies and rats transmitting disease from the disposal site will be diminished.

Project Timescale:

A final report containing the assessment of waste disposal in the tambon, and a proposal for an economically feasible and environmentally sound waste disposal system should be completed by March 2nd, 2002. This report could be submitted to the BCTFN funding committee upon request. The timescale for project implementation is unknown. It is estimated that once the dozer-tractor is obtained, the dumping site could be re-designed or relocated within one month. It may take many months to establish high participation with recycling and back-yard composting.