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Research Article

Utilizing Wasteaware Benchmark Indicators to Improve Municipal Solid Waste Management in Northern Thailand

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Abstract

Primarily responsible for waste collection and disposal, local governments in northern Thailand face significant obstacles in managing waste. Mixing infectious, hazardous and general waste, over-utilizing incinerators and implementing environmentally improper disposal methods all contribute to burgeoning volumes of waste with adverse environmental and health impacts. The objectives of this study are to use the Wasteaware benchmark indicators (WABIs) to assess the effectiveness and sustainability of the waste management of Wiengthoeng Sub-district Municipality (WSM), to identify advantages and disadvantages of its system and offer fact-based recommendations for improvement. Pertinent data was obtained through interviews of governmental authorities, community members and private sector employees between October, 2020 and May, 2021 using designed questionnaires and through review of official governmental records. It was found that with the help of village leaders, increased public participation in MSWM and working with local governments resulted in more widespread involvement in the 3Rs practices. Economic measures facilitated the objectives. Assessing 'pay-as-you-throw' fees resulted in a focus on lowering household costs through waste separation and reduction. The financial benefits of the program were not significant, but the source waste required for final disposal was reduced. The findings suggest that to increase the sustainability of municipal solid waste management, source reduction and segregation should be promoted to minimize the volume of refuse sent to landfills. Source reduction and collaboration between residents and village leaders can provide more long-term benefits than positive short-term economic impacts. Moreover, to improve the sustainability of its physical assets, WSM must better address the environmental impact of waste treatment and disposal.

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Introduction

Managing solid waste presents significant challenges for local governments in developing countries. Despite increasing volumes of solid waste, the majority of these countries lack adequate labor, money, equipment, knowledge, public services and other resources to manage waste in an environmentally safe manner [1]. A study of global MSWM found that service coverage was poor in low-income nations, and that in middle income countries there was a significant volume of garbage in open-dump sites with little or no environmental protection [2]. Open dumping and open burning

are seen as common but unsustainable practices in most developing countries [3–4]. For many low-income countries, waste disposal remains a big issue. Governance concerns are frequent barriers that limit more effective disposal. High capital expenditure and operational costs are also major obstacles [5].

In Thailand, a middle-income country, MSWM needs to be improved by promoting source separation which will ultimately reduce waste. This can also enhance the sustainability of MSWM by minimizing the amount of waste that needs to be disposed of and the environmental impacts of doing so. According to the Pollution Control Department (PCD), 24.98 million tons of municipal solid waste was produced in 2021. 32% of that was sorted at the source and re-used; 37% of the waste was properly disposed of, and 31% was disposed of improperly [6]. The objectives of Thailand's PCD solid waste management 5-year master plan for 2016–2021 [7–8] is that at least 65% of solid waste was to be properly disposed of via environmentally controlled-disposal. The goal was increased to 75% in 2021. In fact, only 34% in 2019 and 37% in 2021 of waste was properly disposed of.

Moreover, improper final waste disposal management causes plastic leakage into the ocean which has adverse effects on the land, sea, and food chain-related human health [9]. Every year, between 4.8 and 12.7 million tons of plastic are expected to reach the ocean from coastal populations around the world. The majority of the world's river plastic comes from Asian rivers. Thailand, Cambodia, Laos, China, Myanmar, and Vietnam are all in the top 20 of sea plastic leakage contributors as reported by Lebreton et al. [10], underscoring the importance of focusing on the Asian countries that are experiencing rapid economic development but have poor waste management. In 2021 in the northern region of Thailand, 4,904 tons of solid waste were generated per day [6]. In Chiang Rai Province, 313 tons of waste per day required final disposal management [11], though there is no transfer station and only 7 proper waste disposal sites compared with 121 improper disposal locations [12].

It is the local governments that are primarily responsible for dealing with solid waste management in an effective and efficient manner. Yet, it is challenging for them to improve the sustainability of their solid waste management [13]. They are legally obligated to promote and support sorting and minimizing waste generation, and they are required to educate, provide knowledge and raise awareness of waste separation, minimization, and recycling. Local governments must place a greater emphasis on waste minimization and household waste management. Concentrating on these practices paves the way for better MSWM sustainability by reducing waste for final disposal and lowering the concomitant environmental impacts [14].

The subject municipality in this study faced a lack of disposal alternatives. Wiengthoeng Sub-district Municipality (WSM) previously disposed of waste at a nearby local government landfill until that landfill closed. That forced WSM to create a closed loop of waste management that included significant resident participation. WSM is an example of a local government that takes an interest in its residents' participation throughout the process of solid waste management, resulting in cooperation, collaboration and good results in all practices [15].

This paper presents an assessment of the solid waste management system of a case study municipality using the standardized methodology of applying Wasteaware benchmark indicators (WABIs).

The Wasteaware benchmark indicators method encompasses all areas of Integrated Solid Waste Management (ISWM) including physical components and governance [16]. Findings using this methodology highlight important concerns that need to be addressed as well as regional strengths. Wasteaware indicators can be applied in any city to assess MSWM performance. Galicia et al. applied the indicator to obtain a desired profile for comprehensive MSWM in Mexico City which helped in addressing the weaknesses and strengths of its MSWM [1]. Azevedo et al. [17] applied WABIs to case studies to do cross-case analysis to find drivers and governance strategies and for feasibility discussions and improvement possibilities. This study's goal is to assess the sustainability of WSM's waste management performance by using WABIs to identify local strengths and rank the most pressing problems.

In addition, an analysis of the resource value (3Rs) aspect can inform guidelines and ideas for designing participatory-based waste management systems for local governments that struggle with high volumes of solid waste. The outcomes of this case study could also be integrated into decision-making processes to improve the city's overall waste management system.

Materials and methods

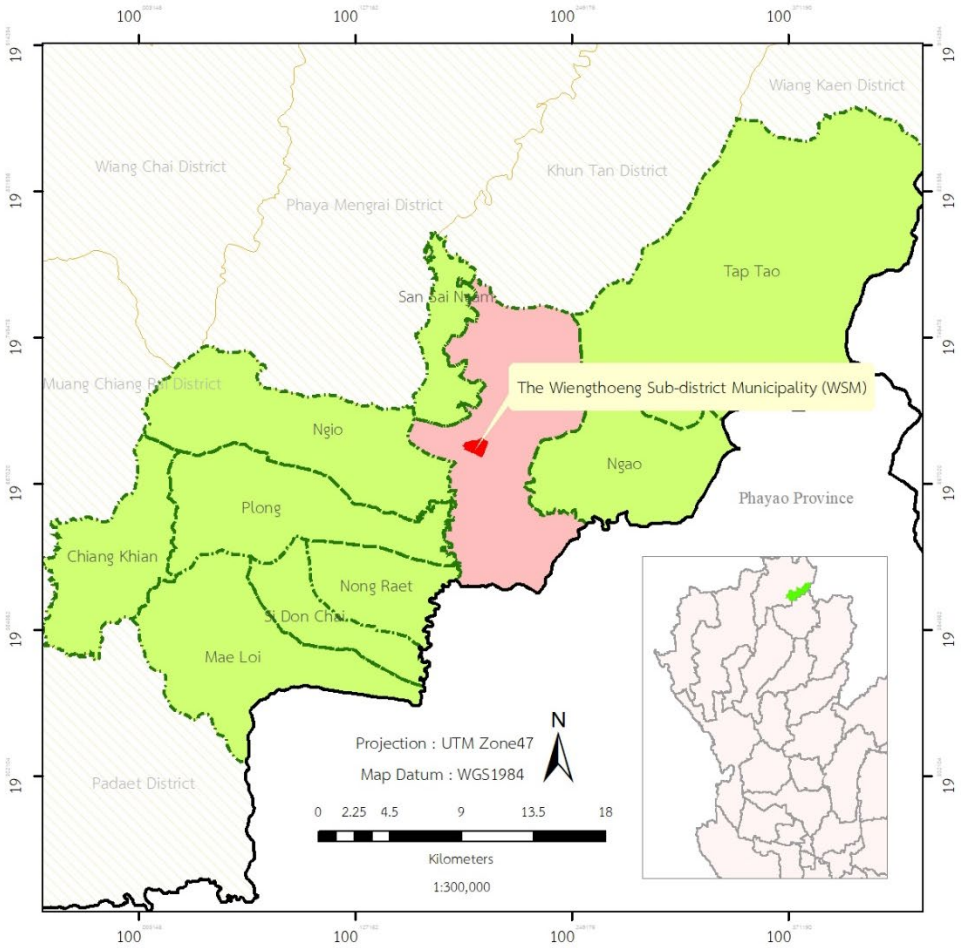
1) Case study profile

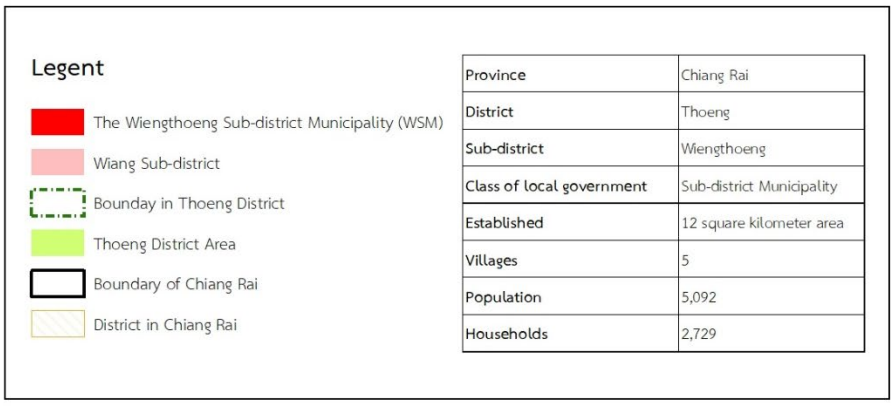
The Wiengthoeng Sub-district Municipality (WSM) is a semi-urban/rural town in Moo 5 of the Wiang Sub-district in Chiang Rai Province's Thoeng District. It encompasses an area of 12 square kilometers and is comprised of five villages with 2,729 households and 5,092 residents (data as of 2021). Most residents earn a

living through commerce and agriculture. Its local policies focus on household waste-related challenges and on initiatives to encourage and prompt household waste separation and minimization. The municipality's policies provide helpful insight for other local governments looking to implement 3Rs practices to address their solid waste management issues.

2) Wasteaware benchmark indicators (WABIs)

In this study, a qualitative and quantitative research method [16] was employed by using the Wasteaware benchmark indicators to assess the process, capacity, and performance of the subject municipality's solid waste management system. This set of indicators is also known as the ISWM benchmark indicators because they are based on the concept of integrated solid waste management. Assessment procedures are outlined in the User Manual for Wasteaware ISWM benchmark indicators [5]. It has been widely accepted that an integrated waste management approach leads to higher system sustainability [18].





Province	Chiang Rai
District	Thoeng
Sub-district	Wiengthoeng
Class of local government	Sub-district Municipality
Established	12 square kilometer area
Villages	5
Population	5,092
Households	2,729

Figure 1 Map of Wiengthoeng Sub-district.

2.1) Conceptual framework

In analyzing solid waste management and recycling performance, the ISWM framework identifies three dimensions: the physical system and its technological components, sustainability issues (social, institutional, political, financial, economic, environmental, and technical), and the diverse groups of stakeholders involved [4]. The UN-Habitat simplified the analysis into two 'triangles' identified as Physical components and Governance (Figure 1). Stakeholders are implicitly included in the process and measurements are centered on inclusivity.

The first 'triangle' focuses on the three main drivers of waste management development which correspond to the three essential, physical, 'hardware' components: 1) public health, which is dependent on a good collection service 2) effect on the environment of waste treatment and disposal, and 3) resource value as determined by the '3Rs'.

The second 'triangle' presents ISWM 'software,' or governance strategies for delivering a well-functioning system. The components are: 4) inclusion, which allows both service users and providers to contribute and benefit 5) financial sustainability, which ensures that solid waste management services and activities are cost-effective and accessible, and 6) a robust institutional foundation and pro-active policies [16].

The Wasteaware benchmark indicators are designed to make use of current data rather than requiring new research. The findings are designed to provide an overview of a city's solid waste management performance, highlighting which aspects are doing well and which are not, pointing the way to future steps on the road to improvement, and allowing benchmarking against other cities. Score results are presented based on traffic light color coding [16].

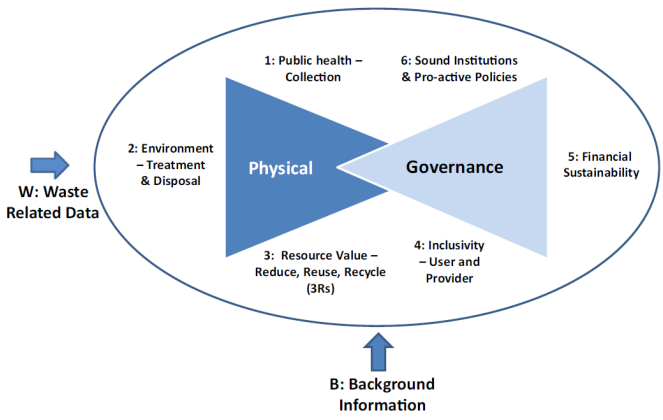


Figure 2 The Integrated Sustainable Waste Management (ISWM) framework [16].

Using the standardized Wasteaware benchmark indicators has benefits at both the national and local levels. ISWM benchmark indicators are designed to work in both developed and underdeveloped nations [16] and can assist in discovering good practices for waste management systems and provide pertinent data for national solid waste management roadmaps and master plans. Additionally, Wasteaware indicators can highlight significant issues that need to be addressed and can be used to track changes over time [20].

3) Data collection

Data was collected between October 2020 and May 2021. Secondary data was analyzed, in-depth interviews with 7 municipal authorities, 3 community members, and 2 private sector employees were conducted, and surveys of waste management locations and services were performed. Where available, key information was gathered through interviews or secondary sources such as local government reports, research papers and government publications. Self-surveys or site visits were utilized to assist in the assessments of several metrics. A range of quantitative data from WSM's formal reports and ordinances found on the municipality's website was key information for waste-aware indicators and confirmed the reliability of the data.

The details of data collection are as follows:

• Inquire into solid waste management practices by using the designed questionnaire shown in the supplementary material

• Conduct semi-structured interviews using the designed questions shown in the supplementary material and focusing on key successes and challenges of MSWM. The key successes and challenges aspect of MSWM focuses on it as a closed loop project, which reflects all MSWM processes; the project encompasses everything from how WSM created this project, cultivates stakeholder participation, prepares tools and procedures, implements it in the village, and monitors and appraises its progress and effectiveness. The supplementary materials contain all of the designed questions.

• Present the Wasteaware benchmark indicator practices prior to the in-depth interview and survey process

• Evaluate solid waste management capacity based on the Wasteaware benchmark indicators and request additional data from municipalities

• Present the Wasteaware benchmark indicator results, obtain feedback and consider results

• Invite all participants to a meeting to: 1) publish research results determined by the application of the indicators 2) promote source separation and waste minimization toward sustainable solid waste management using the results as a guideline

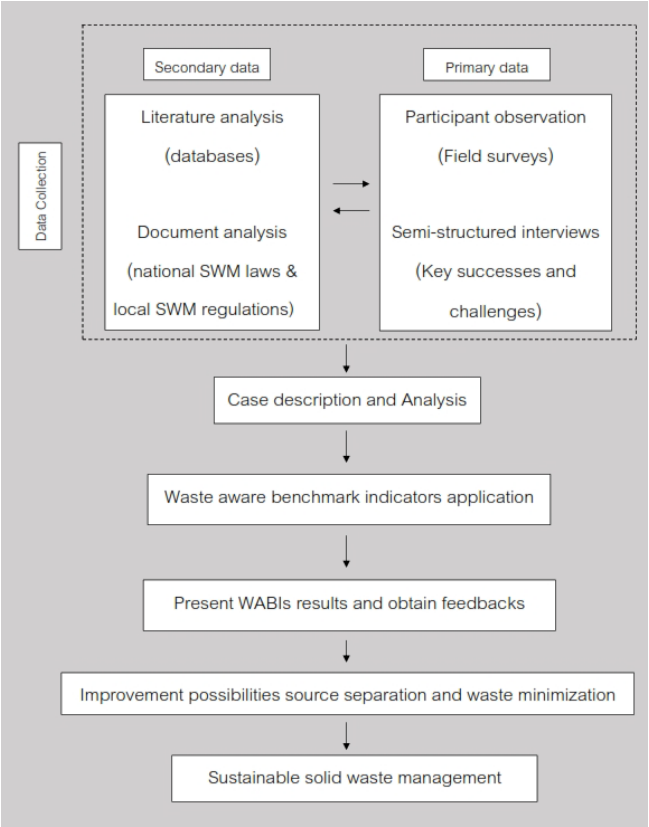


Figure 3 Research Steps

To obtain the data required to complete the assessment, the user manual for Wasteaware ISWM Benchmark Indicators supporting information is referenced and applied, Wilson et al., 2014 [5]. The User Manual provides step-by-step guidance on how to complete the indicator set. WSM has shown that it can be good practice for local governments to apply its methods and promote the 3R's in addressing solid waste management challenges. To assess solid waste management and recycling performance by using ISWM benchmark indicators, data that supports many indexes must be collected and applied. For instance, analyzing solid waste management's physical components must synthesize the data related to indicators: 1. public health: waste collection (1.1 waste collection coverage, 1.2 waste captured by the solid waste management and recycling system, and 1C quality of waste collection and street cleaning service 2. waste treatment and disposal (2 controlled treatment and disposal and 2E quality of environmental protection of waste treatment and disposal) and 3. resource value: 3Rs: reduce, reuse, and recycle (3 recycling rates and quality of 3Rs: reduce, reuse, and recycle: provision). For more details, see the description column in the supplementary material.

4) Data analysis

The entire data set was inputted into the Wasteaware automated excel indicator form which has been developed to simplify the methodology's application. The scoring system adhered precisely to Wasteaware's requirements. The coding aimed to convert both the qualitative and quantitative data collected into five levels of traffic lights, where low = red, low/medium = red/orange, medium = orange, medium/high = orange/green, and high = green. The Wasteaware manual included coding instructions for each indicator. The coding for qualitative indicators established numerical ranges that were expressed as a color code. The guidebook also included detailed coding instructions for qualitative indicators. Scores between 0 and 20 from a number of sub-indicators were added to create composite indicators.

Results and discussion

1) Assessment of MSWM in WSM

Background information of WSM and key waste-related data

The WSM is a medium-sized local governmental entity responsible for five villages in a 12–km^2 area. There are 2,729 households and 5,092 inhabitants. 84 tons of municipal solid waste was generated monthly, 1,008 tons annually. This equated to 0.55 kg/person/day [21]. To provide some numerical context, the 'Clean Province' solid waste management action plan of 2020 reported a nationwide weighted average rate of 1.02 kg/person/day. Chiang Rai province's average rate of waste creation was 0.62 kg per person per day in 2004 [14] and was similarly at 0.69 kg per person per day in 2022 [6]. More importantly, in 2011 before WSM began to implement the strategies discussed herein in 2013, it had a generation rate of 1.25 kg/person/day, which is more than twice the 2021 amount. This comparison is evidence of the effectiveness of WSM's approach described in this study.

Like other local administrations, WSM historically struggled with managing their solid waste. Excess amounts of solid waste compelled WSM to establish protocols to address the problem. In response, WSM developed management practices which emphasized resident involvement and began with village leaders agreeing to invest in an incinerator to address the problem. However, the volume of daily waste eventually far exceeded the incinerator's capacity, and it proved to be an ineffective long term solution as trash

simply accumulated. Upon further analysis, the determination was made that resolving the problem required involvement by all stakeholders, as they discovered that a significant contributor to the excess trash was unsorted waste. Therefore, it became apparent that encouraging proper source separation was needed.

WSM's conclusions and remedies to the incineration shortcomings led to a civil contract between the local people and their administration called Thammanoon Pollamuang (Directly translated as population agreement). Households and state offices in the sub-district were parties to this agreement that outlined community waste management responsibilities. The agreement called for the municipality to provide containers, collect hazardous and general waste, and managed a schedule for selling and recycling waste. Guidelines on utilizing organic waste were also included. The agreement was distributed to all households to disseminate the information and prompt implementation. See a timeline of the history of WSM's solid waste management in Figure 4.

Awareness of the environment and a positive attitude toward waste recycling are not sufficient to maximize involvement, though both can influence environmentally conscious behavior [22]. The ABC-theory (attitude, behavior, and condition) suggests that the greater the accessibility to the process and supporting equipment, training and knowledge the greater the participation. Providing information and tools, such as waste sorting equipment in every household, should be an area of focus to ensure what the households need is easily accessible to them [23].

2) Physical components

Indicator 1, Public health-Waste collection, is divided into two sub-indicators: 1.1 Waste collection coverage, and 1.2 Waste captured by the system. WSM reported that its collection services covered all areas for which it was responsible. All households were required to separate waste. They were given a choice of different levels of collection services and fees. WSM reported that all solid waste that originated in their jurisdiction was systematically managed. Either the community managed its own waste, or the municipality provided waste collection and disposal service to everyone. Illegal solid waste litter was minimized. Respondents reported that the rare new resident or visiting non-resident appeared to be the source.

WSM received a 'high' (green) rating on Waste-aware benchmark indicator 1C for Quality of waste collection service due to the fact that there is no visible waste accumulation in the area. There were no roadside garbage bins to be emptied and no solid waste collection points except for a centrally located, dedicated hazardous waste drop-off bin. The roads are clean and litter-free. Staff who are in charge of waste collection and disposal are provided gloves, boots, and masks. Health and blood checks are also conducted regularly.

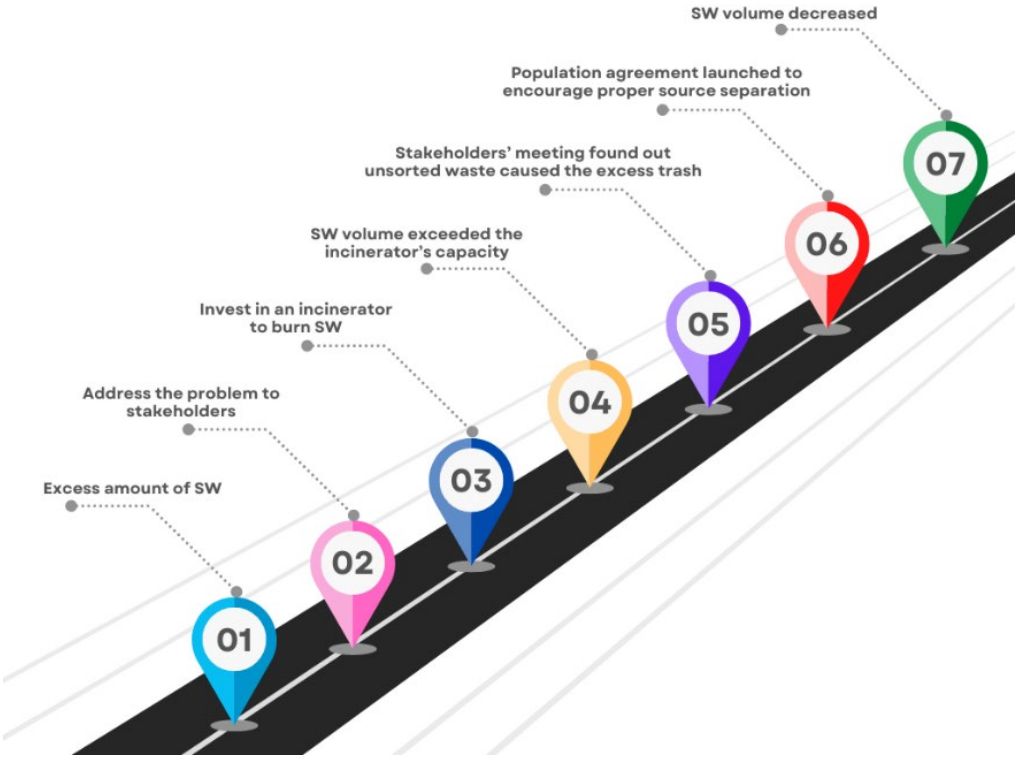


Figure 4 Timeline of WSM's Solid Waste management history.

The indicator, environmental control – waste treatment and disposal, is broken down into two sub-indicators: 2 controlled treatment and disposal and 2E quality of environmental protection. About 67.8% of the solid waste was subjected to controlled treatment and disposal resulting in a low/medium (red/orange) rating. The waste disposal plant is located near the municipality office. There is no fence surrounding the building. (Figure 5(a)) Plastic scraps intermingled with organic matter indicate that the composting process needs to be improved. The quality of environmental protection was medium-high (orange/green).

The resource value – 3Rs: reduce, reuse and recycle indicator was broken down into 3 recycling rate and 3R quality of 3Rs-reduce, reuse, recycle-provision. WSM promoted 3Rs practices in two ways, separation of recyclable waste and recycling organic waste (composting or using a green cone waste digester).

WSM's philosophy conforms to the concept of waste hierarchy whereby it ranks priorities in handling waste based upon what is best for the environment. Top priority is prevention whereas disposal in the landfill is the least preferred. This focus on separation and minimization also facilitate the production of refuse derived fuel (RDF).

Open and honest communication proved to be important for WSM in boosting participatory management. WSM received the maximum score for its provision of knowledge and encouragement of environmental awareness. It provided a guidebook to residents that detailed waste management in general, the history of waste problems, the evolution of waste management, the 3Rs practices and seven approaches to waste management. It increased awareness and encouraged separation and minimization. WSM's leadership and regulation of the waste management project was crucial in successfully promoting the 3Rs. Emphasizing public involvement in recycling efforts can improve the efficacy of WSM's waste management system, while the recycling rate can reflect the management system's waste reduction effectiveness [18].

Though WSM only realized an 8.8% return of the total cost of management, the economics provide an incomplete and superficial assessment of the overall benefits. The intangible benefits of WSM's management counterbalanced the quantifiable economics of the practice. Community empowerment, effective source separation and the minimization of the waste requiring disposal are positive aspects that don't necessarily impact the financial bottom line. In addition, less disposal and associated costs means less environmental harm.

Manomaivibool et al. [14] substantiated that garbage should be managed and sorted at its household source. Simple home composting systems would enable daily organic waste disposal without the need for more resource-taxing collection services. There is a direct correlation between knowledge, opportunity, and access to tools to recycle and attitudes about recycling. Waste reduction trainings and information campaigns are crucial to providing the requisite knowledge, in-form proper attitudes and facilitate involvement in recycling programs [24]. Educational programs motivate children and adults to think and act sustainably [17]. Participation of the general public in recycling programs is critical to boost recycling rates. Social recognition and economic incentives could prompt increased voluntary action (19%–36%) and upgrade organic waste separation efficiency (>50%) [14–24].

WSM was not without its shortcomings as the composting area had no fence (Figure 5(b)), there was no environmentally controlled sewerage system, residual garbage-produced water was found in a container near the trash drop-off point (Figure 5(c)) that was neither maintained nor monitored. Kiln ashes also needed better environmentally conscious management (Figure 5(d)).

In 2020, WSM reduced the volume of waste requiring final disposal from 6 tons per day to 0.25 tons per day. The local governmental leaders' focus and multi-faceted plan to secure public involvement to address the waste management problem were vital to this success. Educating the community about the waste crisis, establishing the village leader-resident agreement for participatory waste management based on the 3Rs, and a pay-as-you-throw scheme to promote waste sorting and minimization using colored flags for sorting were all crucial components to the plan. The ability of households to choose their scope of involvement, to choose their level of service and their cost, and the benefits inuring to the community through funded scholarships and community activities with the money saved incentivized involvement. In addition, WSM charged no fee for collection and/or disposal of separated organic waste or clean waste with flammables as these could be sold to a private company for RDF purposes. Wasteaware indicator 3 showed a 'high' (green) rating for WSM's recycling rate.

Figure 5 Pictures showing (a) waste disposal site, (b) composting area, (c) stagnant water from garbage and (d) ashes from the kiln.

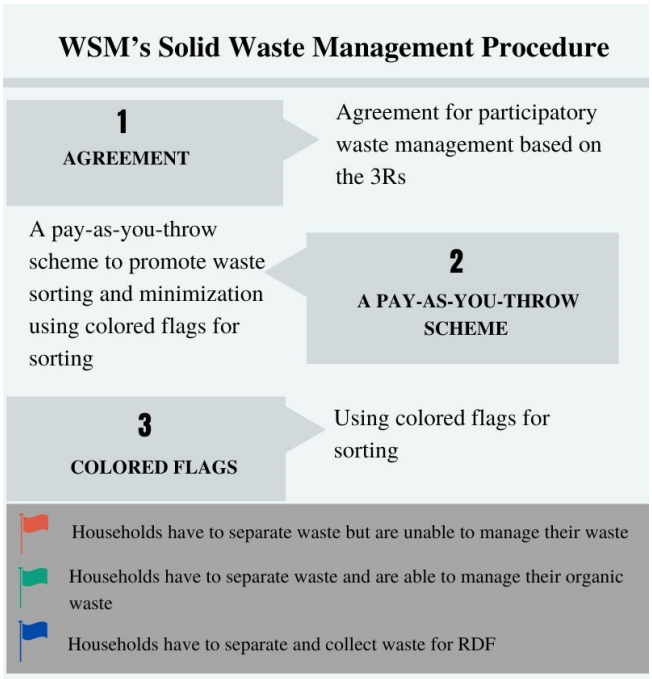


Figure 6 WSM's solid waste management procedure.

3) Governance factors

The governance factor of inclusivity addresses user inclusivity and provider inclusivity.

Indicator 4U was used to evaluate WSM's user inclusivity and it earned a 'high' (green) rating. Producer inclusivity was rated as 'medium/high' (orange/green) by Indicator 4P.

Historically, WSM had difficulties dealing with a waste volume of 6.3 tons per day as it had no disposal site. It became crucial to involve the public in resolving the problem. Public meetings began in 2013 leading to the creation of the Thammanoon Pollamuang, an agreement between the residents and the village leaders that promoted involvement in all stages of waste

management. Pursuant to this agreement, residents were involved in planning, implementing, improving, developing and reaping the benefits of management efforts. Residents were involved in the door-to-door waste collection service provided by WSM which included weighing of trash and providing residents the opportunity to be involved in sorting and monitoring their waste loads. Eventually, the Provincial Office for Local Administration recognized Chiang Rai province as an example of good waste management practice.

WSM provided a manual on waste management. It explained the significance of the waste problem, the concept of management, regulations, suggested practices, potential benefits/rewards, the 3Rs. The manual led to enhanced cooperation and more effective waste management. It mobilized environmentally conscious youth with a focus on waste minimization and separation under a program called 'Trash Hero'. WSM emphasized community involvement and empowerment but not cooperation with the informal recycling sector (IRS). One reason was that there was no IRS in the district. WSM was also able to sell RDF components to a private company, further reducing the volume of waste for final disposal. The results revealed that WSM had much better cooperation with communities than with the IRS.

The analysis of financial sustainability by applying Indicator 5F yielded a positive outcome with a 'medium/high' (orange/green) rating and a normalized score of 71%. This was in spite of WSM receiving only 8.8% (THB 224,600, US $671.14) in collection and disposal fees of the overall cost of management (THB 2,550,549.27, US $6,620.14). The reduction of waste needed for final disposal is evidence that WSM was effective at motivating people to separate their waste at the source. Fees received from households pursuant to the pay-as-you-throw program were part of the overall economic calculation of the plan. As people paid less, the volume of waste that needed to be managed by WSM was concomitantly reduced. More fees and higher receipts meant more end-of-the line trash for disposal.

The evaluation of the adequacy of national solid waste management and Local institutional coherence related to Sound institutions, proactive policies was performed by applying Indicators 6N and 6L, respectively. The national solid waste framework was rated medium (orange) with a normalized score of 46%, the lowest score in the evaluation of all indicators. Evaluation of local institutional coherence resulted in a medium/high rating and a marginalized score of 79%.

On the national level, law and regulation redundancies, a lack of sufficient and/or clearly defined authorities for stakeholders and insufficient financial and skilled human resources all had adverse effects on local efforts. In addition, there were no effective national laws or organizations tasked with monitoring local waste management. What national laws on solid waste management did exist did not play a crucial role in supporting local waste management. In fact, quite the opposite, as it has been discovered that national laws were impeding the local government's pursuit of sustainable solid waste management as they affected the regulatory control and enforcement capability at the national and local levels [13–20].

Possible solutions to these issues are first, repealing overlapping laws and enacting a single, unifying legislation. Second, a national solid waste management organization should be established and be responsible for policy formation, support, and ideas, and to monitor local governments' waste treatment, environmental disposal protections and overall management. Third, the government should have a budget to financially support local government efforts to provide basic solid waste management. Fourth, the government should financially support local waste collection, transportation, and disposal systems, and help address the problem of improper waste disposal and its resulting environmental harm Kallayanapattharasit [13].

The following Figure 6 and Table 1 provide an overview of the general findings of WSM's waste management performance based on WABIs.

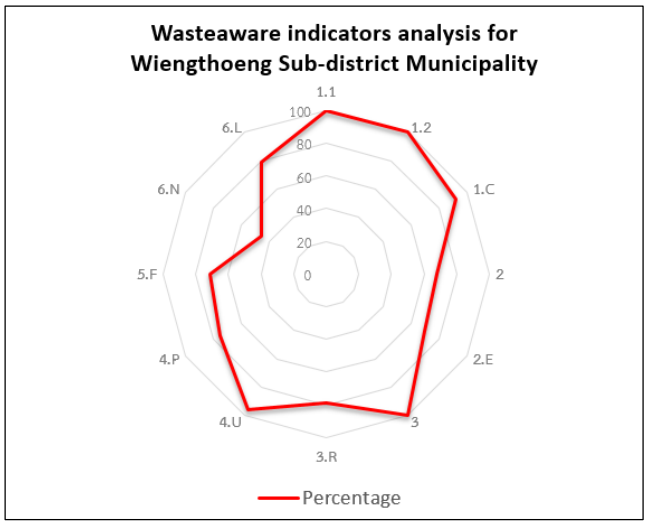


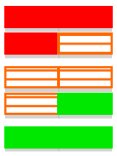
Figure 7 Radar graph summarizing Wasteaware ISWM benchmarking indicators analysis for WSM.

Table 1 Wasteaware ISWM benchmark indicators of WSM

Background information on the city							
City		**Wiengthoeng Sub-district Municipality**					
Country		Thailand					
Date since previous application of indicators				*No previous application of indicators*			
B1	Country income category	World Bank income category		(GNI per capita)			
		Upper Middle-Income Economy		7,260 USD			
B2	Population	Total population of the city		5,092			
B3	Waste generation	Total municipal solid waste generation (tons/year)		714.9			
No.	**Category**	**Data/Benchmark indicator**		**Results**	**Code**		**Progress**
Key waste-related data		**Data**			-	-	-
W1	Waste per capita	MSW per capita	kg per year	200.75	-	-	
			kg per day	0.55	-	-	
W2	Waste composition:	Summary composition of MSW for 3 key fractions – all as % wt. of total waste generated		-	-	-	-
W2.1	Organic	Organics (Food and green wastes) %		30.20	-	-	-
W2.2	Paper	Paper %		22	-	-	-
W2.3	Plastics	Plastics %		49	-	-	-
W2.4	Metals	Metals %		10	-	-	-
W2.5	Solid waste density	Solid waste density		180	-	-	-
W2.6	Moisture content	Moisture content		25-30 %	-	-	-
Physical components		**Benchmark indicator**		-	-	-	-
1	Public health – waste collection	1.1 Waste collection coverage		100	100	100	
		1.2 Waste captured by the system		100	100	100	
1C		Quality of waste collection service		92	**92**	**92**	
2	Environmental control – waste treatment and disposal	Controlled treatment and disposal		68			
2E		Quality of environmental protection of waste treatment and disposal		70			
3	Resource Value – 3Rs: reduce, reuse, recycle	Recycling rate		100			
3R		Quality of 3Rs – reduce, reuse, recycle - provision		79			
Governance factors		**Benchmark indicator**		-			-
4U	Inclusivity	User inclusivity		96			
4P		Provider inclusivity		75			
5F	Financial sustainability	Financial sustainability		71			
6N	Sound institutions, proactive policies	Adequacy of national solid waste management framework		46			
6L		Local institutional coherence		79			

Key for colour coding:

- Low: Red
- Low/Medium: Red/Orange
- Medium: Orange
- Medium/High: Orange/Green
- High: Green



Key for abbreviations:

- B- Background information
- W – Waste Information
- 1 C– Public Health.
- 2 E– Environmental Control
- 3 R– Resource Mgmt.
- 4U- User inclusivity
- 4P – Provider inclusivity
- 5F – Financial sustainability
- 6N – National Framework
- 6L – Local institutions.

Source: University of Leeds [5].

Conclusions and recommendations

The MSWM systems employed by the WSM were found to have both strengths and limitations. Various physical components, such as bench-mark indicators 1.1, waste collection coverage and 1.2, waste captured by the system, were strengths. They both achieved a score of 100%. The quality of waste collection services attained a 92% score by Indicator 1C. The recycling rate as evaluated by Indicator 3 also achieved 100%, which reflects the effectiveness of WSM's practice of encouraging community involvement.

In both controlled treatment and disposal (low/medium) and quality of environmental protection (medium/high), the application of Indicators 2 and 2E respectively revealed weaknesses The quality of 3Rs, Indicator 3R, obtained a medium-high score (orange/green) and exposed the practice in which organic compost was not carried out in accordance with environmental control rules.

Governance indicator 4U revealed a strength. WSM educated, prompted and supported households in participating in source management and capacity building. It also was involved in monitoring waste sorting and collecting fees for waste collection. Applying indicators 4P provider inclusivity and 5F financial sustainability resulted in medium/high (orange/green) ratings. The success of WSM's waste management prompted other governmental and non-governmental organizations to provide financial support as well. Waste sorting helped reduce the volume of waste that needed to be disposed of as well as the cost associated with that disposal. Applying indicators 6N and 6L revealed that the lack of a consolidated national waste management organization and clear regulations created major challenges to sustainable solid waste management by local governments.

The results of utilizing WABIs to assess Wiengthoeng's waste management demonstrate that, based on the concept of waste hierarchy wherein the prevention of waste is top priority, WSM's solid waste management is approaching sustainability. The waste is sorted, recycled and reused to the extent possible, and generally managed to reduce the volume of waste that requires final disposal. WSM's solid waste management revealed effective ways for similarly situated local governments to adhere to the hierarchy concept and establish a waste management system that prioritizes minimization and source separation. The legislative and economic measures implemented were effective in encouraging environmentally friendly consumer behavior and can be used as examples. The pay-as-you-throw principle works well to incentivize people to practice waste reduction and source separation, saving them money if they do so. Cultivating an environmentally friendly consciousness among young people through learning by doing, particularly waste reduction and separation based on the 3Rs, as WSM did with the Trash Hero program, is a sound strategy. However, WSM needs to improve its controlled treatment and disposal aspects. For instance, kiln ashes need better environmentally conscious management. In addition, the waste disposal site needs a fence enclosure to prevent the wind from blowing waste away.

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