

Manual on

PLASTICS LEAKAGE PREVENTION FROM FORMAL AND INFORMAL RECYCLING FACILITIES



NONTHABURI, THAILAND



RRC.AP
Regional Resource Centre for
Asia and the Pacific



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for Marine Plastic Debris



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This study was conducted for the Regional Knowledge Centre for Marine Plastic Debris (RKC-MPD), Economic Research Institute for ASEAN and East Asia (ERIA)

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Chapter 1



Introduction

1.1 Background

Over the past decade, Thailand's waste management system has undergone significant transformations. Despite these changes, the country continues to grapple with various challenges, including limited public participation, inadequate institutional support, and low investment in the sector. Waste management activities involve both the formal and informal sectors. The formal sector, operating through private-public partnerships (PPP), manages waste collection, transfer, and disposal, covering a spectrum of activities such as collection, transfer, diversion, and disposal efforts (CCAC, 2015). On the other hand, the informal waste sector consists of waste pickers, unregistered junkshops, recyclable waste mobile shops (itinerant waste buyers), collectors, and sorters, playing a pivotal role in post-consumer plastic recycling in Thailand.

Plastic waste recovery and recycling face significant challenges, leading to a substantial portion of plastic waste being disposed of rather than recycled. Ineffective sorting processes contribute to plastic waste mixing with municipal solid waste (MSW), ultimately ending up in landfills. Studies show that up to 80% of mixed plastic waste is contaminated, rendering it unsuitable for recycling. Two primary challenges inhibit progress in plastic waste recovery. Firstly, the absence of a systematic sorting and collection system results in contamination from the mixing of plastics with other solid waste. Challenges in waste separation, such as inadequate facilities and public cooperation with formal collection operations, adversely affect recycling activities. Furthermore, alongside inadequate infrastructure and private sector capacities, the Thai Government lacks a comprehensive action plan to incentivize the utilization of recyclable and compostable plastic products. The informal sector, serving as the main driver behind recycling efforts, lacks the necessary capacity, financial backing, and technology to enhance plastic recovery and ensure efficient, high-quality recycling. The complex nature of plastic materials, characterized by various polymers and

composite materials, further complicates the recycling process.

Efforts aimed at boosting recycling, such as public awareness campaigns and the establishment of recycling infrastructure, have not significantly increased the recycling rate. This is primarily due to limited access to recycling facilities, inadequate recycling technology, and inadequate funding for recycling programs (Ounjai et al., 2022). Addressing these challenges demands investment in recycling capabilities, improving the waste management infrastructure, and implementing policies that promote sustainable plastic waste management practices. Proactive promotion of policies supporting a sustainable circular economy, including the adoption of environmentally friendly products, is essential. Collaboration and cooperation among all stakeholders, including the government, private sector, and citizens, are required to work toward a more sustainable future for Thailand. Additionally, given their crucial role in the Thai waste management process, special attention must be given to the informal sector. Therefore, the development of manuals and guidelines for recycling industries is crucial to reduce plastic leakage.

1.2 Objectives

The manual aims to support both formal and informal recycling enterprises in preventing plastic pollution by advocating best practices and promoting proper housekeeping within informal recycling facilities. Drawing insights from Nonthaburi Municipality, the manual includes the following:

- Advocating improved environmental management practices at both macro- and microplastic levels by plastic industry stakeholders and informal recyclers.
- Offering reference guidance to key players in the plastic recycling sector to encourage the adoption of more efficient operating practices.
- Promoting the adoption of sustainable practices within the plastic production and recycling

industry, encompassing both formal and informal sectors.

1.3 Scope of the Manual, Study Area, and Existing Initiatives

This section presents the scope of the manual, study area and existing initiatives in Nonthaburi Municipality.

1.3.1 Scope of the Manual

The scope of the Manual is outlined below:

1. The manual focus on the potential land-based sources of plastic leakage into water sources stemming from mismanaged waste disposal and logistical mishandling by informal recycling groups.
2. It is developed based on a situational analysis report, incorporating both primary and secondary data sources. Secondary data are derived from literature reviews, with primary data gathered through field visits, stakeholder interviews, and a stakeholder consultation workshop.
3. The study area for these manual is Nonthaburi Municipality and its surroundings.

1.3.2 Study Area

Nonthaburi, Thailand's largest municipality and seventh-largest city, is situated adjacent to Bangkok and covers an area of 38.9 square kilometers. Once characterized by fruit orchards, it has undergone significant urban development, now boasting government offices, commercial establishments, and residential areas. The municipality features natural canals and ditches originally utilized for transportation. Its terrain is mainly flat, with the Chao Phraya River running through it. Nonthaburi shares borders with Pak Kret Municipality to the north, the Laksi District of Bangkok to the east, Bang Sue of Bangkok to the south, and Bang Kruai District of Nonthaburi Province to the west. The area is home to 44 public water sources, primarily utilized for drainage, flowing from east to northwest into the Chao Phraya River.

Nonthaburi Municipality was chosen as the focus of the study due to the significant challenges it faces in municipal solid waste management (MSWM) stemming from population growth, migration, rapid urbanization, and economic expansion. According to a 2019 study by the Pollution Control Department of Thailand, Nonthaburi Municipality generates approximately 551.38 tons of MSW per day, with 14.1% constituting plastic waste. Moreover, numerous communities within Nonthaburi City Municipality are closely associated with canals, exacerbating waste accumulation issues. Proximity to the river has facilitated the flow of waste from neighboring households into nearby waterways, compounding the problem.

Furthermore, a study conducted in March 2021 and 2022 across five provinces along the Chao Phraya River, namely Samut Prakan, Bangkok, Nonthaburi, Pahum Thani, and Phra Nakhon Si Ayutthaya, revealed a significant presence of microplastic debris. The findings indicated that during both wet and dry seasons, the Chao Phraya River received substantial microplastic input, with Samut Prakan and Nonthaburi contributing the most. PET emerged as the predominant polymer type, followed by PP, with the majority of microplastic fibers detected during the transfer into the river and subsequent transport to the sea (Jendanklang et al., 2023).

Efforts to tackle the plastic waste issue in Nonthaburi Municipality have included initiatives such as enhancing waste separation at source, promoting reusable bag usage, and enforcing waste management regulations. However, more comprehensive measures are needed to effectively address the plastic waste management challenges in the area.

1.4 Existing Initiatives in the Study Area

Nonthaburi Municipality is actively spearheading several waste management initiatives, demonstrating a commitment to sustainability. One such initiative is the "Travel Thailand in Style, Reduce Plastic Waste" campaign, a collaborative effort involving the Tourism Authority of Thailand and various public and private stakeholders. This campaign aims to

promote responsible tourism practices and reduce plastic waste. Additionally, the “Wor. Won” initiative encourages recycling through a drive-thru service for waste plastic bottle collection, while weekend recycling markets facilitate the management of recycled materials. Another noteworthy program is the “Community Seedling for Environmental Protection,” which educates youths on environmental monitoring techniques.

Furthermore, collaborative programs like the annual “Big Cleaning Day” and the canal cleaning project known as “The Heroes conducted canal dredging and clearing” are actively underway. These initiatives play a vital role in raising awareness among the local population about the importance of reducing plastic usage and the significance of recycling. Through these concerted efforts, Nonthaburi Municipality is striving to create a cleaner, more sustainable environment for residents and visitors alike.

1.5 Target Users of the Manual

The target users of the manual encompass a diverse array of stakeholders involved in various aspects of waste management and plastic recycling within Nonthaburi Municipality.

- Government officers engaged in public health and environmental services play a pivotal role in

formulating and implementing policies related to waste management and environmental protection.

- The Local Government Unit (LGU) of Nonthaburi Municipality with responsibility for overseeing and coordinating waste management efforts within its jurisdiction.
- Informal stakeholders, such as waste pickers and recyclers/junkshops, as integral participants in the informal recycling sector, contributing significantly to waste management activities.
- Clean production or recycling centers, which are in the processing and recycling of plastic waste, thereby playing a crucial role in mitigating plastic pollution, and promoting sustainability.
- Associations of plastic recyclers represent the collective interests of professionals and organizations involved in plastic recycling, advocate best practices, and foster collaboration within the industry.
- Other actors within the plastic industry include manufacturers, distributors, and retailers, whose activities impact plastic waste generation and recycling efforts.

By targeting these key stakeholders, the manual aim to provide valuable advice and support to enhance plastic waste management practices, promote sustainable solutions, and contribute to a cleaner and healthier environment within Nonthaburi Municipality.



Chapter 2



Gaps in Policy, Institutional Arrangements, Technology, and Resources

2.1 Existing Policy/Regulations

Thailand's plastic waste management policy, influenced by international commitments and trade agreements, includes the Action Plan on Plastic Waste Management Phase II (2023–2027). This plan, with voluntary sector participation, aims to tackle plastic waste issues and has led to a ban on plastic waste imports from certain countries. However, the ban does not cover the recycled plastic resin crucial for production. Nonthaburi municipality showcases progress in waste management and recycling, yet challenges persist due to limited information, especially within the informal sector. Effective governance requires comprehensive information and stakeholder communication. The private waste management sector, mainly small and medium enterprises, lacks organized associations for government engagement. Key gaps in policies include insufficient frameworks to connect national strategies with local policies, weak governance of guidelines, and inadequate approaches for engaging stakeholders, particularly in the informal sector. Recommendations include supporting the informal waste sector and enhancing engagement between LGUs and all waste actors, both formal and informal, through effective policies and resource allocation.

2.2 Institutional Arrangements

Waste management in Thailand involves coordination between the national government, local authorities, and private sector entities. The national government establishes laws and standards to control funding, while local governments oversee waste collection, disposal, and recycling and enforce policies. At the local level, Nonthaburi Municipality manages solid waste, including plastic waste, through collaborations with various stakeholders and community engagement. This includes educational campaigns, waste separation initiatives, and reducing plastic usage in local businesses. The Office of Public Health and Environment supervises

waste and sewage management, pollution control, and natural resource regulation. Within Nonthaburi, the Division of Environmental Health Service formulates policies and oversees the Solid Waste and Waste Management Department, specifically tasked with managing plastic waste. However, certain regulations, such as the Town Planning Act, can pose challenges. For instance, restrictions on establishing antique shops in community areas under the Act led to these shops operating outside the city, such as in Sai Noi, resulting in logistical difficulties for waste sorting and increased transportation costs. Overall, Nonthaburi has multiple agencies and regulations dedicated to addressing plastic waste management at the local level, with the Nonthaburi Municipality Office as the main agency and the Nonthaburi Municipal Regulation on Solid Waste Management 2008 as the primary legislation.

2.3 Technology

Technology plays a vital role in tackling plastic waste by revolutionizing waste management systems and promoting recycling efforts. For instance, Nonthaburi City Municipality has introduced innovative solutions like “The Floating Garbage Collectors of Nakornnont,” crafted from recycled plastic bottles, to mitigate waste in water sources. These collectors filter out large debris, averting drainage issues and curtailing waste flow into the Chao Phraya River.

Access to technology is pivotal for combating plastic pollution among informal recycling enterprises for several reasons. Firstly, technology fosters innovation and collaboration within the waste management sector, spurring the emergence of novel solutions and business models. Through partnerships with tech providers, informal recyclers in Nonthaburi can receive training and support to adopt state-of-the-art tools and techniques for managing plastic waste. Embracing technology-driven innovation enables these enterprises to bolster their competitiveness and resilience amidst environmental challenges.

Moreover, technology facilitates streamlined operations for informal recyclers through tools like sorting machines and bailers, reducing contamination risks and leakage during handling and processing. Enhanced recycling technologies also boost efficiency, enabling recyclers to process larger quantities of materials. This, in turn, allows them to diversify their recycling capabilities and contribute to a more circular economy.

Furthermore, access to technology improves data management and information sharing, enhancing transparency and accountability in trading and market access. Digital platforms for sharing information and trading recyclable plastics reduce information asymmetry, foster inclusiveness, and diminish the rejection rate of plastics, ultimately advancing market knowledge and transparency.

Table 1. Summary of identified gaps and recommendations

Gaps	Recommendations
Resources aspects	
<ul style="list-style-type: none"> Inadequate waste management infrastructure and facilities. Insufficient skilled workers for pre- and post-processing recycling. Limited access to finance for eco-friendly solutions and alternative plastic processing. Inadequate market access for recycled materials, limiting their sale. High market uncertainty discouraging investments in plastic waste management. 	<ul style="list-style-type: none"> Enhance waste management infrastructure. Offer training for informal workers (e.g., itinerant buyers, junkshops) in waste collection and recycling. Provide financial support options for informal waste actors, led by the national government and local government units (LGUs). Establish network transparency and information sharing. Forge partnerships with the formal sector to secure markets for the informal sector.
Technology aspects	
<ul style="list-style-type: none"> Inadequate waste management infrastructure and facilities. Insufficient skilled workers for pre- and post-processing recycling. Limited access to finance for eco-friendly solutions and alternative plastic processing. Inadequate market access for recycled materials, limiting their sale. High market uncertainty discouraging investments in plastic waste management. 	<ul style="list-style-type: none"> Enhance waste management infrastructure. Offer training for informal workers in waste collection and recycling. Provide financial support options for informal waste actors, led by the national government and local government units (LGUs). Establish network transparency and information sharing. Forge partnerships with the formal sector to secure markets for the informal sector.
Institutional aspects	
<ul style="list-style-type: none"> Lack of communication and cooperation between informal sectors and the government regarding waste management. Weak collaboration between local government, private sector and public sector. Limited monitoring of informal shops and recycling facilities. Lack of incentives to support stable operation of junk shops /recycling facilities. Lack of knowledge capacity of the government which includes absence of databases of plastic volume and lack of situational assessment regarding plastic waste management in the municipality. 	<ul style="list-style-type: none"> Enhance waste management infrastructure. Offer training for informal workers in waste collection and recycling. Provide financial support options for informal waste actors, led by the national government and local government units (LGUs). Establish network transparency and information sharing. Forge partnerships with the formal sector to secure markets for the informal sector.

2.4 Resources

With essential resources, recycling enterprises in Nonthaburi can significantly curb plastic pollution among informal recyclers. However, lacking proper infrastructure and equipment, these recyclers struggle to manage plastic waste efficiently, risking environmental leakage. The shortage of skilled workers exacerbates inefficiencies, necessitating training to handle waste properly and prevent contamination. Financial constraints hinder investment in sustainable technologies, limiting the potential for scaling. Improved funding access is sought for equipment upgrades and infrastructure enhancement, reducing operational costs.

Limited market opportunities hinder informal recycling ventures from marketing recycled materials effectively, potentially leading to improper disposal or illegal dumping. Collaborations with formal sector counterparts could establish reliable revenue streams, promoting adherence to waste management protocols. Market uncertainties further deter investment in plastic waste management, as recyclers hesitate due to uncertain future conditions and demand. The stakeholders' provision of resources and assistance can empower informal recyclers to adopt sustainable practices, mitigating the risks associated with plastic pollution and leakage.



Chapter 3



Value Chain of Plastics and Resin Pellets in the City

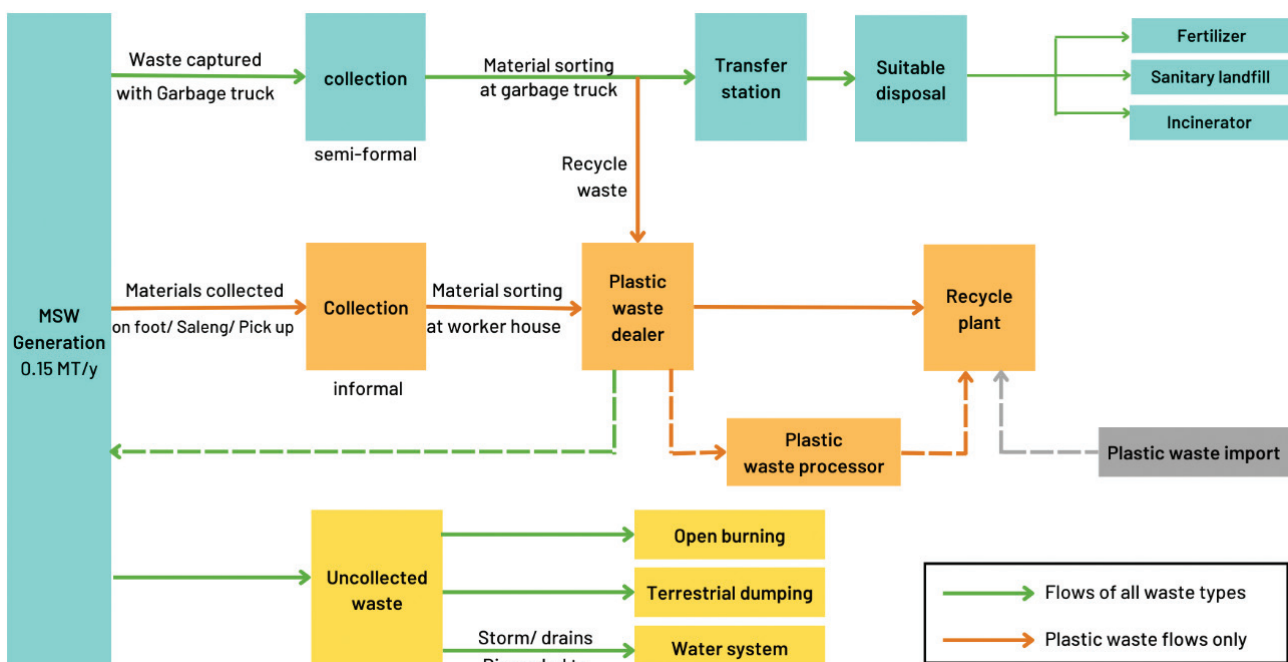
In Nonthaburi, the inner city hosts fewer junkshops, mainly relying on manual workers to collect waste from households and nearby businesses. This collected waste is subsequently transported to recycling factories within the province and in Pathumthani. During a site visit, various types of junkshops were identified, each with distinct characteristics:

- *Small-scale shops:* Primarily purchasing plastic waste from nearby households and selling it to larger shops or factories within Nonthaburi Province.
- *Medium-sized shops:* Collecting waste from scavengers (Saleng), with the collected waste then sent to factories in Pathum Thani and Chonburi Province.

- *Large-scale junkshops:* Gathering waste from scavengers (Saleng) and smaller junkshops, selling it to Pathum Thani Province.
- *Special large-scale shops* in the Sai Noi area: Collecting waste from households, scavengers (Saleng), waste pickers, and other smaller junkshops.

Figure 1 illustrates Nonthaburi Municipality's plastic material value chain. In the formal sector, waste is collected by the municipality and transported to landfills using green trucks. The Nonthaburi Provincial Administration Organization (NPAO) supervises waste disposal through licensed private organizations. Junkshop owners have confirmed that non-recyclable waste is disposed of in landfills. Moreover, plans are in place to establish a waste-to-energy treatment plant by 2024. In the semi-informal and informal sectors, collectors gather

Figure 1. Value chain of MSW and plastics waste in the city¹



Source: Study Team based on Google Map



plastic bottles and sell them to plastic collection shops within the municipality. Waste pickers gather waste from various sources, including homes, communities, and landfills, selling it to plastic collection shops or junkshops. These shops then sort plastic by type and color before selling it to factories for washing, grinding, melting, and pelletizing services since they avoid these processes due to high costs and a lack of human resources.

Nonthaburi Municipality faces a surge in plastic waste, threatening public health and water quality, particularly in view of its proximity to the Chao Phraya River. Annual waste generation stands at 268,855.4 tons, with 16.5% being plastic and 40.3% food waste (Tangwanichagapong et al., 2017). LDPE, HDPE, and polyester contribute

significantly to leakage, often ending up in landfills or water bodies due to limited recycling options. The informal sector, grappling with fluctuating waste prices and inadequate infrastructure, exacerbates the problem, with unprocessed plastic residues and illegal dumping posing additional risks. During transportation, low-value plastic waste is prone to leakage, further complicating the issue. While Nonthaburi's informal waste recycling system reduces landfill waste, challenges persist, including the absence of landfill disposal facilities and communication gaps with authorities. Despite efforts to support the informal sector, accurate data on plastic leakage are lacking, hindering effective waste management. Despite strides in modern waste management, plastic leakage remains a pressing issue in Nonthaburi.



Chapter 4



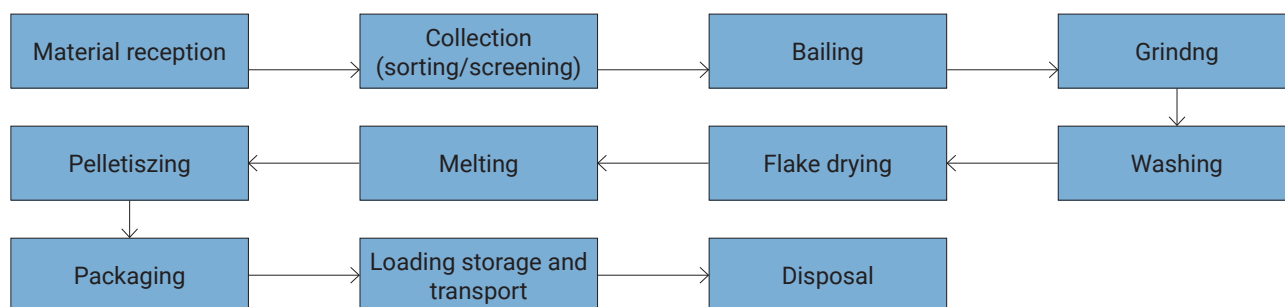
Recycling Process in Nonthaburi Municipality

Adhering to a systematic recycling process is vital for mitigating the environmental consequences of plastic waste and fostering sustainable waste management strategies. This involves implementing preventive measures, effective containment practices, and efficient clean-up protocols. The subsequent section provides an in-depth analysis of the present state of plastic waste recycling within the city, supported by case studies, underscoring the imperative for comprehensive plastic waste recycling practices.

4.1 Recycling Process and Current Status of Nonthaburi Municipality With Case Studies

Most of the facilities surveyed were involved in receiving plastic waste materials, sorting them, and then selling them to other recycling factories. These secondary facilities carry out additional recycling processes such as baling, grinding, washing, and drying. Table 2 provides a detailed breakdown of this process. However, the study indicates that only

Figure 2. Plastic recycling process (Source: Adapted from GIZ (2023))



Source: Study Team based on Google Map

Table 2. Process for plastic recycling

Process	Objective
Material reception	Receive waste from various sources
Sorting	Separate plastic bottles and other plastics for recycling. Separate the label using a label remover machine or remove manually the labels that are hard to remove. Separate colored and transparent PET, HDPE bottles and other bottles.
Bailing	Compress the plastic into cubes and store properly to avoid leakage
Grinding	Crush plastic bottles and lids to the appropriate size i.e. flakes, permit easy separation between bottle and lid. Check for residues and clean the area after grinding to reduce leakage
Flake washing	Wash to clean the flakes
Flake drying	Dry to remove water from the flakes and ensure moisture in the material output
Melting	Melt the dried flakes
Pelletizing	Cut into pellets
Packaging, storage and transport	Pack the finished product to transport it to other facilities and manufacturers
Disposal	Dispose generated waste that cannot be further reused or recycled using appropriate disposal method

Source: Adapted from GIZ (2023)

a limited number of recycling factories, such as Indorama Ventures, have been operating a complete recycling process from start to finish.

In Nonthaburi Municipality, the recycling facilities visited operate legally. They focus on efforts to

maintain a clean environment, minimizing noise and odors, and regularly cleaning the site area. However, challenges such as reduced plastic waste prices and labor shortages are prevalent. As a result, some plastic factories choose to import plastic waste for recycling for cost-effectiveness.

Recycling Facility 1: medium-sized family-owned businesss

At Recycling Facility 1, a licensed medium-sized family-owned business, various types of waste are purchased, with plastic comprising the highest volume at 0.5 to 0.8 tons per day. The junkshop acquires waste from households, saleng, and waste pickers. Upon receipt, plastic bottles are separated from labels, and different plastic varieties are segregated based on type and color, with prices set accordingly. The compressed plastic bottles, particularly PP and PET, are then sent to recycling factories, including Indorama Ventures in Chonburi Province and nearby facilities. Due to the high cost associated with plastic recycling, the junkshop refrains from washing, grinding, and altering the forms of plastic materials. The owner recognizes the importance of preventing plastic waste spillage, attributing such occurrences primarily to informal waste collectors. Furthermore, the owner advocates government initiatives to encourage waste separation at the household level.

Recycling Facility 2: Medium Junk shop

At the second site, a medium-sized licensed shop located within the city area focuses on sorting waste. Despite being situated in a residential area, the shop does not receive complaints regarding odor or noise. During our visit, we observed staff actively maintaining cleanliness in the area. The shop primarily sources plastic waste from households and communities, purchasing various types of waste including metal, paper, glass, and plastic. Approximately 0.6 tons of waste are collected daily, with 1 to 5% deemed non-saleable after separation. Plastic bottles are segregated based on type, and sorted materials are sent to factories in Pathumthani. The shop relies on manual labor for segregation to minimize transportation costs. Non-recyclable and residual waste are collected and sent to the landfill by the municipality. However, the shop faces challenges, such as the lack of a permanent buyer for plastic bottles, resulting in fluctuating prices and uncertainty regarding income stability. Municipal authorities conduct yearly inspections during license renewals.



Recycling Facility 3: Medium Junk shop

At the third site, a medium-sized licensed junk shop sorts of various types of waste, including plastic, metal, and copper. While the shop earns more profit from metal and copper due to a stable market, it focuses on PET bottles for plastic waste, receiving 500 to 600 bottles daily. Approximately 5 to 10% of plastic waste remains non-recyclable after segregation. The shop primarily collects plastic from saleng, as household waste selling has declined due to limited profit margins. The owner suggests government intervention to establish standard market prices for materials. After sorting, the shop sells the plastic bottles to factories for further processing, as it lacks grinding and palletizing facilities. Non-recyclable plastics are disposed of in landfills, both independently and by the municipality. Despite facing price fluctuations due to imported plastics, the shop has permanent and backup buyers for plastic waste. Labor shortage is another challenge, with declining interest among Thai individuals to work in junkshops. The shop undergoes yearly monitoring by the municipality during license renewal. During the site visit, compartments for segregating plastics were observed, although some waste was found outside covered areas, raising concerns about potential leakage during adverse weather conditions. However, the owner believes that daily cleaning practices mitigate the risk of plastic leakage.

Recycling Facility 4: Small Junk shop

The fourth recycling facility, is a small-sized licensed junk shop that collects household and community waste from the surrounding area, receiving approximately 0.02 to 0.03 tons of waste per day. While the shop mainly receives sorted PET and PE bottles, it occasionally segregates plastic waste, resulting in a higher rate of non-sellable plastic waste (10 to 20%) due to unskilled labor involvement. Unrecyclable plastics and residues are transported to the landfill by the municipality. Unlike some other sites, regular municipal monitoring does not occur; instead, the municipality conducts yearly inspections during license renewals. Price fluctuations in plastic waste also pose challenges for the owners of this junk shop, mirroring issues faced by other sites.

Recycling Facility 5: Large scale

Recycling Facility 5a licensed large-scale recycling facility in Sainoi municipality, stands out for its size and equipped with a grinding machine and space for pallet washing, although currently unused due to a lack of qualified workers. Despite receiving high volumes of waste, labor shortages hinder effective waste separation and management. The facility accepts all types of waste from households, saleng, and waste pickers, processing around 2 tons of plastic waste bottles, focusing on HDPE, PE, and PP. Sorted bottles are sold to factories in Bangkok and Samut Prakan. Concerns about potential leakage during handling were expressed. Formerly processing 10 tons of waste per day with a shredder, reduced emphasis on PVC due to low quality and profit. Post-separation, there's usually 1% non-recyclable plastic residue, disposed of in a nearby private landfill. The owner highlighted challenges posed by chemical mixing in plastic factories, affecting plastic value. Price fluctuation remains a challenge, akin to other sites.

Chapter 5



Guidance for Plastic Leakage Reduction

The burgeoning population and urbanization in Nonthaburi Municipality, alongside insufficient waste management infrastructure, pose significant challenges. This situation risks escalating plastic pollution within the municipality, leading to detrimental effects on the environment and public health. Harnessing the potential of the informal recycling sector could offer a promising solution to mitigate these challenges. Therefore, it is crucial for the municipal government to adopt holistic strategies such as a) minimizing plastic waste generation, b) improving recycling facilities, and c) empowering the informal sector. The following guidance on the reduction of plastic leakage is proposed:

1. **Acknowledge Challenges:** Recognize the challenges posed by population growth, urbanization, and inadequate waste management in the municipality or city.
2. **Understand Impact:** Understand how these challenges can worsen plastic pollution, leading to harmful effects on the environment and public health.
3. **Identify Solution Components:** Highlight the key components necessary for addressing these challenges:
 - reducing plastic waste,
 - improving the recycling infrastructure, and
 - strengthening the capacity of the informal recycling sector.
4. **Explore Potential Strategies:** Delve into potential strategies to tackle these challenges effectively.
 - **Implement Plastic Reduction Measures:** Initiate measures to minimize plastic waste generation through campaigns, regulations, or incentives.
 - **Enhance Recycling Facilities:** Invest in a better recycling infrastructure such as collection points, sorting facilities, and processing plants.
 - **Support the Informal Recycling Sector:** Provide training, resources, and incentives to informal

recyclers to improve their efficiency and expand their role in the recycling process.

- **Emphasize a Comprehensive Approach:** Stress the importance of implementing a comprehensive approach that addresses all three components simultaneously for maximum effectiveness.

Hence, it is important to highlight the urgency of action and the potential positive impact of implementing these strategies in the municipality or city.

5.1 Reduction at Source

An important challenge in waste management is waste reduction at source. Even in conditions where there is adequate infrastructure in place to recycle waste, the first step should be to reduce waste generation and take steps to minimize the costs attached to waste sorting and recycling. Therefore, steps must be taken to change the consumer's behavior at home or in the workspace. This requires knowledge of the importance of waste management, including sorting home waste that can be recycled. Therefore, the municipality should take steps to ensure people are aware of the importance of sorting waste. To achieve this goal, the municipality might need to create a community-based waste management model where waste collection and sorting occurs at the community level rather than the household level, with incentives designed to ensure sorting steps are followed (Fatmawati, 2022). The popular Waste Bank Initiative, which is currently being implemented in various cities across Thailand, is an example of training and incentives being provided at the local level to ensure households follow proper sorting practices (Fang, 2020). Another similar initiative is the Rayong model, currently being implemented in various areas of Thailand. The model places emphasis on raising awareness among locals on the importance of cleaning and sorting plastic waste to make recycling easier. The model also provides incentives for the locals to sell well-sorted and cleaned plastic materials in the market to

provide an extra source of income for the community (Piyasrithong, 2020).

These initiatives demonstrate the crucial role local communities can play in reducing non-recyclable waste and improving the circular economy. Beyond these initiatives, the local government can also intervene by promoting reusable or biodegradable bags to reduce the use of plastic materials. Alternatively, waste pickers could be encouraged to transition from dumpsites and street picking to door-to-door collection. This transition could be facilitated by establishing cooperatives for formal sector plastic waste recycling actors. These cooperatives could offer incentives such as salaries or other forms of social security to waste pickers. Additionally, providing access to high-value plastic waste alongside low-value plastic waste, like the approach adopted by SWaCH (a waste pickers cooperative in Pune, India), authorized by the Municipal Corporation, could further incentivize participation. This process involves providing access to door-to-door waste or community-based waste instead of some informal workers having to rely on scavenging plastic waste from dumpsites. Since plastic material collected near the source of emission tends to be higher than that collected near dumpsites, this reduces the leakage gap. This initiative can help reduce waste leakage (Velis et al., 2022).

Moreover, Nonthaburi Municipality has initiated projects aimed at waste reduction. For instance, it has been promoting community waste reduction by establishing a community leaders' group under a sustainable waste management project. Under this project, the municipality organizes a weekend recycling market to encourage proper management of recyclable office materials. According to the reports, to date six weekend recycling markets have been opened. The municipality can expand these types of activities to promote reduction at source.

In addition, during the site visit, the waste plastic bottles sold to the junkshops by the households and the communities were observed to be sorted beforehand. This indicates that communities and individual households are taking the initiative to sort their plastic waste at source before selling it to junkshops or waste collectors, further mitigating the chance of plastic leakage.

5.2 Improvement in Infrastructure and Technical Capacity

Besides enacting customized policy measures aimed at reducing waste at source, it is crucial that the technical abilities and incentives of local actors, including communities, be boosted to effectively achieve waste management policy goals. In addition to enhancing technical knowledge and incentives, it is essential to ensure that local communities have sufficient infrastructure for sorting and disposing of waste. This entails the municipality investing in classified waste collection bins. Thus, investment is necessary at the community level to provide adequate waste collection and sorting facilities, enabling communities to make informed waste management decisions. At present, the municipality has been collecting sorted recyclable and non-recyclable waste in the same collection vehicle, and no landfill exists within the Nonthaburi Municipality. This situation increases the possibility of leakage. Evidence from the field visits shows that developing the capacity of the informal sector and going beyond empowering the local communities are crucial for the development of the sector. Improving the capacity of the informal sector might include providing training to improve the human resource capacity and devising mechanisms to increase cooperation and coordination between the formal and informal sectors. The partnerships between the informal and formal sectors are important for addressing plastic leakage. For example, the City of Phitsanulok, which has a strong partnership between the formal and informal sectors, was able to prevent 95% of its waste from going to landfills. Similar efforts can be made in Nonthaburi City.

Providing financial assistance and incentives based on the municipality's capacity can address the informal sector's lack of resources for investing in machinery and infrastructure. Supporting the informal sector in this way can enhance recycling quality, especially considering the efficiency of the formal sector. Additionally, the government could invest in essential facilities like landfill sites, machinery, and storage facilities, possibly establishing a facility bank for informal sector use. Improving data governance is crucial in Nonthaburi Municipality to accurately track plastic usage, its value chain, and its recycling status. However, this effort may face challenges due to the presence of

numerous unregistered informal waste management actors and plastic plants located outside the municipality.

Efforts to regulate the informal sector in Nonthaburi involve formalizing the informal waste management system through junkshop regulations. These regulations include guidelines for designated areas, size requirements, and trash handling capacities. While some junkshops are regularly inspected every two months, others have minimal local government involvement, with inspections typically occurring yearly during license renewal.

high volume and low value. To address this, waste collectors, especially in the informal sector, should be incentivized to collect such low-value plastic. This could involve providing greater social security, such as higher wages or insurance coverage, or increasing the price paid for plastic waste. Some studies recommend factoring in environmental costs when pricing plastic to make waste collection more profitable for collectors; the city government could consider implementing such a system (Velis et al., 2022).

Table 3 provides guidelines for different sectors, including the government, informal, and private sectors, to address the issue of plastic leakage.

5.3 Incentivizing Plastic Collection

Data from site visits indicate that collecting certain types of plastic waste poses challenges due to their

Table 3. Guidelines for different sector to reduce plastic leakage in Nonthaburi Municipality

Local Government	<ul style="list-style-type: none"> Promote community-based waste management for source collection and sorting. Raise awareness among locals about proper waste management practices. Foster partnerships between formal and informal sectors to boost waste management capabilities. Implement routine inspection and monitoring of recycling facilities and plastic waste movement to prevent leakage. Enforce compliance with waste management and recycling regulations. Offer financial support and incentives to informal sectors for enhanced recycling. Invest in waste management infrastructure for improved sorting and disposal. Enhance data governance mechanisms for better tracking and management of waste.
Informal plastic waste recyclers	<p>Management Practices</p> <ul style="list-style-type: none"> Enhance door-to-door waste collection over dumpsite and street picking. Provide incentives for collecting low-value plastic waste to mitigate leakage. Improve human resource capacity through training and skill development. Establish, implement, and regularly monitor internal site audit plans. <p>Human Resource Practices</p> <ul style="list-style-type: none"> Train employees in identifying and sorting plastics by type, color, and recyclability. Ensure proper storage of segregated and unsegregated plastic waste to prevent leakage. Maintain regular cleaning of the recycling facility. Use secure and leak-proof transportation vehicles for plastic waste transfer. Employ appropriate disposal methods to reduce plastic waste leakage. Keep detailed records of plastic waste received and sold at the junkshop.
Private sector industries	<ul style="list-style-type: none"> Employ biodegradable packaging to reduce unrecyclable plastic usage. Promote the reduction of single-use plastic. Invest in and support new initiatives and technologies to decrease plastic leakage. Collaborate with local government and the informal sector to educate them on the adverse effects of plastic waste leakage. Review internal site audits of junkshops and recycling facilities, encouraging proper waste segregation, and recycling practices.

Source: Study Team

Chapter 6



Internal Site Audit

Internal Site Audit

Internal site audits are crucial for monitoring site performance and ensuring compliance with regulations. They involve regular monitoring and documentation to identify and prevent potential leakage. Trained auditors are essential for accurate data collection. The following steps should be taken when scheduling an internal site audit:

- Establishing a multidisciplinary audit team.
- Training auditors before initiating internal audits.
- Creating an audit checklist or questionnaire for data collection.
- Conducting interviews with key personnel involved in operations.
- Gathering data at every stage of the recycling process.

- Centralizing and organizing collected data for analysis.
- Identifying potential areas of plastic leakage for remediation.
- Compiling a detailed report summarizing audit findings, including quantitative data and key insights.
- Highlighting areas needing improvement or efficiency.
- Offering recommendations and proposed solutions.

Table 4 presents a sample checklist for the internal site audit to quantify the level of leakage and identify proper methods for improvement.

Table 4. Sample checklist for internal site audit

Process	Question	Finding (Yes/No/NA)	Level of Leakage (%)	Scope of Improvements
Material reception	Are the plastics separated properly into recycling?			
Collections and Segregation	Have the handlers conducted any of the following activities: Sort by plastic type Remove labels (if applicable) Wash the plastics properly to prevent contamination			
Bailing	Are all the segregated plastics bailed properly into cubes?			
Grinding	Are the bailed plastics being grinded? Have there been any evidence of microplastics around the grinders?			
Washing	Are the plastic flakes properly washed? Are there any signs of leakages during the transport from washing to drying process?			
Flake Drying	Are there any leakages when the flakes are put into dryers? Are there any leakages when the flakes are taken out of the dryers for melting?			

Continued next page

Table 4 continued

Process	Question	Finding (Yes/No/ NA)	Level of Leakage (%)	Scope of Improvements
Melting	Are all the flakes melted without spillovers?			
Pelletizing	Are there any signs of leakages during the pelletizing process?			
Packaging, Storage and Transport	Have the handlers conducted the following activities: Package and seal the pallets properly Store in the designated areas Transfer the properly packaged pallets into the transportation			
Disposal	Are the non-recycled plastics sorted properly? Are the non-recycled plastics properly packaged and put into transportation? Are the vehicles' storage doors closed properly?			

Source: Adapted from Sustainable Electronics Recycling International, (2014)





Chapter 7



Remediation Options With Available Technology Practices

7.1 Current Practices for Reducing Plastic Waste

Nonthaburi City Municipality has implemented the project “The Floating Garbage Collectors of Nakornnont,” which involves recycling plastic bottles to reduce water pollution. These collectors filter large garbage to prevent water drainage issues and reduce the amount of garbage entering the Chao Phraya River. Additionally, various technologies are being explored to combat plastic pollution, including robotic technology for water pollution capture and microplastic collection methods using sand filters

The following are some technologies introduced in Thailand:

➤ SCG-DMCR Litter Trap: A mechanism designed to trap marine debris on the surface without

allowing it to flow back out with the tide. It has a maximum capacity of 700 kg (SCG, 2019).

➤ KoomKah: A mobile application streamlining the waste buying process, making it faster and more convenient to organize data. It provides real-time, accurate, and traceable data from both the buyer and vendor to support waste management initiatives (SCG, 2020).

7.2 Current Practices for Recycling Plastic Waste

Nonthaburi City is currently in the process of implementing the waste-to-energy concept to recycle waste. The initiative is scheduled to start in 2024 (Warapetcharayut, nd). Other existing practices for plastic waste recycling in Thailand and outside are outlined in the following sections:

Table 5. Different types of a high scoring technologies

Technology Name	Sector	Description	Geographical focus
Plastic Bank	Land- Based	Recycling ecosystem in coastal communities incentivizing the collectors. Operated under a blockchain technology that ensures transparency and traceability	Haiti, Brazil, Indonesia, the Philippines, and Egypt, with wider application potential
Project STOP		Sustainable waste management system that follows four step approach, selecting cities and assessing, designing systems, implementing with support and expanding to new regions	Indonesia in the coastal cities of Muncar in East Java, Lekok and Ngulign in Pasuruan in East Java, and Jembrana in northwest Bali, with wider application potential
StormX Netting Trash Trap	Rivers, Streams and Harbors	Capturing system that collects both floatable and non-floatable waste. Efficient for waste filtration at sewers and pipe outfalls	North America; Asia; Africa; Australia
Trash Wheel		Technology that collects floating waste powered by renewable energy requiring manual operation	Baltimore, Maryland, USA, with plans to expand to Newport Beach, California and Panama City, Panama

Source: Winterstetter et al. (2021)

7.2.1 Formal Sector

Indorama Ventures has implemented innovative PET bottle recycling projects, establishing recycling plants in various countries, including Thailand. At Indorama, they collaborate with the informal sector to source plastic bottle waste and transform all types and colors of PET waste into valuable resources through a series of steps. For the recycling process, they wash and chip the waste bottles into rPET flakes. Some flakes are further melted into recycled fibers and yarns which can be used in the textile industry, with others turned into packaging material and bottles for the manufacturing industry (IVPCL, 2021). Alongside their recycling activities, Indorama Ventures promotes awareness raising on waste separation and plastic recycling. They engage with various target groups, including the government, private sector, and school students. Through their educational initiative, they focus on the importance of waste management and recycling PET bottles into valuable resources (IVPCL, 2023).

7.2.2 Informal Sector

Informal waste workers, including individuals and small to medium enterprises are economic actors who excel in exploring economic opportunities often overlooked by others. They are engaged in activities such as buying/selling recyclables, waste collection and operating small recycling workshops. Consequently, they also require similar technical, financial, and management capacities to those in the formal sector. However, they are excluded from services due to their lack of legal status.

Establishing a cooperative incorporating the informal sector into the formal sector and providing them with salaries or other forms of social security could be an initiation for improving the conditions of the informal sector. Iloilo in the Philippines has implemented one such initiative through the establishment of a waste workers association called USWAG Calahunan Livelihood Association Inc (UCLA), officially registered as a formal business enterprise, allowing workers to jointly recover waste

materials. In addition, they also gain access to alternative opportunities for income generation, such as creating handicrafts from recycled packaging and producing compost (GIZ, 2011).

7.2.3 Collaborative (Formal and Informal Sectors)

Extended Producer Responsibility (EPR) is a policy approach whereby producers are responsible for the environmental impacts of their products and packaging from production to disposal. Currently, EPR has received much attention from various countries, including Thailand, for its ability to address plastic pollution and promote a shift toward a circular economy (Vassanadumrongdee and Manomaivibool, 2022). Moreover, it provides waste pickers and the informal waste sectors the opportunity to become involved in designing greener jobs and driving transformation through systematic training (Talbot et al., 2022).

One of the companies in Thailand applying a broad range of EPR-related measures is Amway (Thailand) Company, Limited, which takes back waste and recycles it. The company offers a range of products in concentrated forms, helping to reduce packaging size and materials. The packaging is also manufactured to decompose naturally. In addition, the company initiated a campaign entitled "I'm not Rubbish" to collect used packaging, which is recycled and used to make bags. This campaign encouraged Amway members to return used packaging, earn points, and exchange them for ecological travel programs (Chotichanathawewong and Thongplew, 2009).

To make EPR a success in Thailand, all stakeholders must collaborate. Firstly, the government should effectively implement and enforce EPR policies. Secondly, the companies need to ensure proper collection and recycling of their packaging. An inclusive system should also be developed, incorporating the informal sector in waste management and recycling. Finally, consumers should responsibly sort and manage their waste.



Chapter 8



Awareness Raising Programs on Plastic Leakage Into the Environment

With increased economic development, population growth, migration, and rapid urbanization in Nonthaburi City, the leakage of plastic and resin pellets has emerged as a major issue. Hence, raising awareness can be an important mechanism for reducing plastic waste and creating a less polluted city. At present, Nonthaburi Municipality is actively promoting various awareness programs with the aim of addressing the waste management issue. Details of some awareness programs for the public mentioned in this section have been obtained from the Nonthaburi City Municipality Annual Report 2021 (Nonthaburi City Municipality, 2022).

8.1 Awareness Raising Program for the Public

- Promoting behavioral change in consumers at home through students by educating them on the negative impacts of plastic leakage.
- Organizing awareness initiatives at the community level to educate individuals on segregating plastic waste from other forms of waste and disposing of it properly, making it easier for the informal sector to reduce the leakage from the source.
- To address the problem of single-use plastic, efforts are being intensified to implement the “Do Good Deeds with the Heart, Reduce Receiving, Reduce Giving, Reduce Using Plastic Bags” initiative in Nonthaburi. The campaign includes encouraging people in retail shops to use cloth bags. Other similar campaigns can be conducted to encourage people to reduce their purchases of single-use plastics.
- Organizing a weekend recycling market to promote the management of recycled materials contributes to sustainable waste management.
- Educating and training students in schools about the segregation of recyclable and non-recyclable materials, as well as involving experts from companies like SCG to teach students about waste management, should be continued.

- Increasing the number of workshops to promote the participation of youths in community environmental surveillance monitoring by providing information about water quality, air quality, and waste in the municipality.
- Conducting a “Big Cleaning Day” with the cooperation of the municipality and other agencies such as educational institutions, communities in the municipality, volunteers, and municipality officers.
- Campaign programs for promoting waste management in religious places are being conducted in the city with the aim of creating awareness and concern among people regarding the 3R principles. More of these campaign programs should be conducted in the municipality and surrounding areas.
- Cleaning and clearing the canals in the municipality to clean the waste dumped, including plastic bottles and foam containers, and enhance the water drainage efficiency of canals in the municipality. This initiative should be continued over time to reduce plastic leakage into the water bodies.
- Promoting sustainable waste management practices through the use of media, including active media signs such as posters in major public areas and social media campaigns reflecting the issues of plastic leakage and its impact on water sources..

8.2 Awareness Raising Program for the Informal Sector

- Organizing technical training on plastic recycling for the informal sector in collaboration with the local government and the formal sector.
- Organizing informative sessions to provide knowledge to the informal sector on the city’s waste Management Master Plan and existing waste management infrastructure on a regular basis.

- » Conducting regular workshops and discussions with the informal sector to identify their concerns, address issues and create awareness of the environment and health impact.





Chapter 9



Checklist for Setting Up Recycling Facilities

This section outlines the steps involved in establishing a recycling facility. It emphasizes the need for proper documentation, research, and planning; selecting an appropriate location and infrastructure; purchasing suitable equipment, machinery, and mode of

transportation; staffing and training; implementing effective collection and segregation systems; managing waste and disposal; and ensuring compliance and reporting requirements. Further details on these topics are provided in Table 6.

Table 6. Checklist to set up recycling facilities

Description	Process
<ul style="list-style-type: none"> • Proper Documentation 	<ul style="list-style-type: none"> • Submit an application at the district or sub-district office with required documents.
<ul style="list-style-type: none"> • Research and Planning 	<ul style="list-style-type: none"> • Identify the type of recycling facility (e.g. PET, LDPE, etc.) • Research local regulations and permits required to operate a recycling facility in Nonthaburi • Determine the scale and capacity of the recycling facility based on the resources and market demand • Prepare a site plan showing the details of space utilization for different components within the establishment. Areas for sorting and collecting recyclable materials
<ul style="list-style-type: none"> • Location and infrastructure 	<ul style="list-style-type: none"> • Find a suitable location, considering factors such as accessibility, zoning regulations and facility size • The location not within a residential zone • The premise should be enclosed by a fence • Within 100 meters of neighboring public facilities, such as educational institutions, temples, hospitals, government office workplaces, natural conservation and environmental preservation areas • Assess the infrastructure requirements that would fulfill major criteria of Nonthaburi Municipality such as buildings, utilities (water, electricity) , and environmental impacts (e.g., pollution) • Oblige with the following building characteristics and sanitation measures: • The facility must have a covered roof and concrete flooring with suitable slope to prevent waterlogging • Measures should be taken to prevent dust, odors and noise generated by machines from causing risk to the health and safety of employees and residents • Fire alarm system and fire extinguishing equipment should be installed in compliance with applicable laws
<ul style="list-style-type: none"> • Equipment, Machinery and mode of transportation 	<ul style="list-style-type: none"> • Identify the specific recycling equipment and machinery needed based on the type of plastics for recycling • Purchase or lease the necessary equipment, such as shredders, balers, sorting machines, conveyors, and compactors • Ensure the equipment meets safety and environmental standards based on local regulations and guidelines • Machinery and tools must be installed on floors or bases specifically designed to support them • Implement safety measures to prevent accidents involving machinery during operation • Purchase or lease transportation vehicle based on efficiency and cost effectiveness

Continued next page

Table 6 continued

Description	Process
<ul style="list-style-type: none"> Staffing and Training 	<ul style="list-style-type: none"> Determine the staffing requirements for the facility Recruit and hire qualified staff members with relevant experience Provide comprehensive training on equipment operation, safety protocols, waste management practices, and environmental regulations Implement safety measures and ensure compliance with labor protection laws and regulations during work Provide adequate personal protective equipment such as gloves, safety shoes and nose covers and ensure that employees dress appropriately Conduct annual health examinations for employees/workers
<ul style="list-style-type: none"> Collection and Segregation Systems 	<ul style="list-style-type: none"> Develop a collection system for different plastic materials from households, landfills or other dedicated collection points Keep records of the quantity of materials purchased, their sources, and the quantity of materials sent for recycling or the unusable waste materials. Establish an efficient sorting system to separate different types of plastic recyclables Implement quality control measures to ensure the purity of recycled plastics Set rates based on different categories of plastic recyclables Display purchasing prices along with specifying the types of materials being purchased
<ul style="list-style-type: none"> Waste Management and Disposal 	<ul style="list-style-type: none"> Set up a waste management system for handling non-recyclable materials generated during the recycling process Use appropriate and sufficient containers Regular cleaning of the containers and the storage area If self-disposal is done, it should be done according to the public health principles with approval from local authorities Implement odor control systems to prevent unpleasant smells, disease vectors to protect the health and hygiene of employees and surrounding area Partner with other waste management companies or local authorities to dispose of non-recyclable waste properly Implement procedures for hazardous waste management if applicable Establish a safe place for storage of hazardous materials to prevent easy access and potential danger or fire hazards, in compliance with the relevant regulations
<ul style="list-style-type: none"> Compliance and Reporting 	<ul style="list-style-type: none"> Ensure compliance with all applicable environmental regulations, permits and reporting requirements by Nonthaburi Municipality Establish monitoring and reporting systems with proper internal site audit Periodically review and update the processes and systems to improve efficiency and sustainability

Source: AFRA, (nd)

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