Technical Guidelines for

# PLASTICS AND RESIN PELLETS LEAKAGE PREVENTION FROM FORMAL AND INFORMAL RECYCLING FACTORIES

HANOI, VIETNAM

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Regional Resource Centre for Asia and the Pacific

Regional Knowledge Centre for Marine Plastic Debris

ERIA
Economic Research Institute for ASEAN and East Asia

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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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# List of abbreviations

| | |
|---|---|
| BAT | Best Available Technologies |
| BEPs | Best Environmental Practices |
| EPR | Extended producer responsibility |
| IFC | International Finance Corporation |
| PPP | Public - Private Partnership |
| SUP | Single Use Plastic |
| SWM | Solid waste management |
| UPOPs | Unintentional Persistent Organic Pollutants |
| VOCs | Volatile organic compounds |
| VPA | Vietnam Plastics Association |

# Contents

# Section 1

# INTRODUCTION

## 1.1 Context

Plastics and their products are widely utilised across various industries and services in Vietnam as well as in numerous countries. In 2021, the global plastic industry market was estimated to reach 593 billion USD[1]. Between 2022 and 2030, the plastic market is expected to expand at a cumulative annual growth rate of approximately 3.7%. In 2021, Vietnam's plastic product exports surged by 34.9% to $4.93 billion USD despite the global impact of the Covid-19 pandemic. Including plastic materials, the total exports reached $2.26 billion USD, marking a 68% increase by 2020. Overall, the plastic industry contributed about $7.19 billion USD to the country's total export turnover in 2021 according to data from the Import-Export Department (Ministry of Industry and Trade, Vietnam).

Studies have estimated that nearly 33% of the 3.9 million tons of plastic waste in Vietnam is recovered and recycled every year[2]. Therefore, approximately 70% of the plastic material's worth is squandered, amounting to approximately $2.2–2.9 billion annually. This has resulted in economic losses for the country and positioned Vietnam as one of the main contributors of plastic waste to the oceans annually. Plastic recycling is a key solution for recovering and retaining the material value of post-consumer plastics. Post-consumer plastic recycling reduces the production of virgin plastics. The production of virgin plastics is energy-intensive and contributes to increased emissions and material consumption. Recycling post-consumer plastics can reduce energy consumption by 75%, waste from ore mines by 97%, and water usage by 40%, among other related factors.

The Vietnam Plastics Association (VPA) projects that the plastic industry will require approximately 10 million tons of raw materials for production and export by 2023. However, the domestic production of primary plastic resins, as outlined in the Master Plan for the petrochemical industry and related projects, is anticipated to reach only 2.6 million tons, meeting only 26% of the demand. Consequently, the remaining 7.4 million tons will need to be imported from foreign sources. Considering this disparity, an effective and prudent solution is to increase the plastic recycling rate. Vietnam has been actively promoting the development of its plastic recycling industry, acknowledging it as a highly effective solution for reducing plastic waste in the environment. However, the plastic recycling sector, which includes facilities in craft villages and informal units in Hanoi, remains fragmented and faces numerous challenges.

As one of Vietnam's largest cities, Hanoi's rapid population growth and urbanisation in recent years have resulted in a significant increase in plastic waste, putting pressure on the city's waste collection and treatment systems. Currently, plastic waste is managed along with other types of solid waste. Plastic waste management regulations are often embedded within solid waste management (SWM) policies, leading to overlapping management responsibilities among authorities. In Hanoi, the daily volume of solid waste is estimated to be 7,000 tons, with plastic waste constituting approximately 17.14% of this total

Currently, plastic recycling craft villages in Hanoi are facing severe pollution issues. Outdated and inefficient recycling technologies result in the excessive consumption of input materials, energy, and water, leading to low recovery rates and high volumes of waste. Additionally, the open burning of discarded plastics and residual waste emits harmful substances such as acid and alkali vapours, volatile organic compounds (VOCs), and unintentionally produced persistent organic pollutants (UPOPs). Untreated processing wastewater is discharged directly into waterways, posing a significant risk of microplastic contamination and resin pellet leakage. While manufacturing activities in certain plastic

1 https://biopolymer.vn/tin-tuc-su-kien/thi-truong-nganh-nhua-nam-2021/

2 World Bank Group. 2021. Market Study for Vietnam: Plastics Circularity Opportunities and Barriers. Marine Plastics Series; World Bank, Washington, DC

recycling craft villages in Hanoi have significantly boosted the economic prosperity of producing households and localities, they often lack strict environmental compliance measures. This has resulted in craft villages becoming significant hotspots for plastic leakage.

## 1.2 Identified gaps

### 1.2.1 Existing policies and regulations

In Vietnam, the highest legislation level is the National Law, which is enforced through regulatory instruments issued by the national government (the 2nd level, such as: decrees, decisions, directives of the Prime Minister or Office of the Government) and then by ministries or provincial/city governments (the 3rd level, such as circular, directives, decisions, official dispatch, and documents).

In Hanoi, plastic waste management aligns with the broader solid waste management framework governed by national legislation, which cascades through regulatory instruments issued by the national, provincial, and city governments. However, existing regulations on plastic waste management are often embedded within solid waste management policies, leading to overlapping management responsibilities among authorities. Key regulations primarily focus on plastic scrap imports, nonbiodegradable plastic bags, recycling initiatives, and ocean plastic pollution prevention.

Hanoi has integrated environmental pollution control measures related to plastic products into its environmental protection and solid waste management plans. Local directives and decisions have been issued to enhance plastic waste management and recycling. Despite the establishment of a legal framework and supportive policies for waste recycling, these gaps remain. Specific guidelines for accessing incentives under the Law on Environmental Protection 2020 are lacking, as are the standards and regulations for recycled products. In addition, clear guidelines on recycling technology selection and the responsibilities of manufacturers, importers, and individuals are needed.

Furthermore, the mechanisms and policies that attract private-sector investment in waste collection and handling facilities, such as tax incentives and land leases, are currently limited. To address plastic pollution effectively, the development and utilisation of substitute/recycled materials and products must be promoted. Policy recommendations include the development of guidelines for circularity and plastics, thereby establishing technical standards for plastic products and recycled plastics and fostering research and innovation in plastics.

The accompanying recommendations include increasing taxes and environmental protection fees for single-use plastic bags and products to reduce consumption. These measures are aimed at supporting sustainable waste management practices and mitigating the environmental impact of plastic waste in Hanoi.

### 1.2.2 Institutional arrangements

Plastic waste comprises all types of solid waste generated by industrial, social, and anthropological activities. Plastic waste management is not separate from SWM, and the problem of plastic waste in SWM currently ranks highest.

As mentioned in the situation assessment report, plastic waste is managed by relevant ministries at the state level and between departments at the city or provincial levels. However, the scope of management and competence allocation between ministries, departments, and sub-organisations at lower levels is not clear. There are no regular meetings for exchanging information among regulatory bodies. These gaps cause inefficient cooperation among the authorities and confusion among under-controlled individuals and entities.

### 1.2.3 Technology and plastic recycling processing

In Hanoi, Vietnam, the adoption of technology in the recycling and waste management sectors is limited. Waste management and sorting rely heavily on manual labour from the informal sector, which collects, sorts, and transports recyclable materials along the value chain. Both the informal and formal recyclers use conventional mechanical recycling technologies. In addition, plastic processing facilities

are inadequately monitored and utilise outdated infrastructure, posing potential health risks to employees and nearby communities. The use of obsolete recycling technologies in craft villages results in inefficient operations, leading to the generation of large volumes of discarded plastics, particulate matter, sediment, wastewater, and energy loss.

**Collection and segregation:** In Hanoi, recycling is primarily conducted manually, with informal waste collectors, known as waste pickers, gathering valuable recyclable plastic. URENCO staff collects the remaining plastic waste using trucks in urban districts, whereas private companies and facilities handle the collection in suburban areas. The equipment and vehicles used for collection are basic and not specialised for different types of solid waste.

**Recycling:** Wet technology is predominantly used in plastic craft recycling villages in Hanoi. Plastic scraps are mechanically recycled into plastic flakes for primary recycling, or into plastic granules and recycled products for secondary recycling. The recycling facilities operation at the household scale using Chinese manufactured machines and equipment with small to medium capacity (0.9 to 2 tons per day, employing 2–6 workers). These technologies offer flexibility and affordability to local recyclers. Several pieces of machinery and equipment in many of the craft recycling villages are either purchased, self-fabricated, or have been in use for over ten years, leading to poor conditions, inefficient operation, material and energy losses, and environmental pollution.

**Storage and transportation:** Loss of plastics during storage and transport can occur owing to various factors. Inadequate packaging and protection may result in the damage or loss of plastics, whereas rough handling or improper loading and unloading procedures can also contribute to breakage or spillage. Exposure to adverse weather conditions, such as high temperature or humidity, can degrade plastic materials and increase the risk of loss. Insufficient security during transport can lead to the shifting or movement of materials, thereby exacerbating the risk of damage or loss. Additionally, limitations in storage facilities and transportation infrastructure may increase the likelihood of loss or damage. Theft or pilferage during storage or transportation poses another risk, as does the lack of monitoring and control over storage and transport processes.

### 1.2.4 Resources

Presently, financial resources mobilised in the SWM (including plastic waste) infrastructure are mainly based on the state's budget and are provided by State-Owned Enterprises, but they do not satisfy practical demand. However, investment in nonpublic financial resources is limited because of the lack of comprehensive policies to attract private investors.

In Hanoi, the inherent difficulties of funding and other resource limitations regarding different perspectives are as follows:

**From regulators and policy makers:** Revenue from waste collection and handling fees is insufficient to build an integrated SWM system owing to the low rate of environmental charges paid by consumers and taxpayers; an incomplete legal framework that complicates the provision of detailed instructions and allocation of enforcement responsibilities; and the layout for sites of treatment facilities that encounter local citizens' disagreement.

**From collectors and pre-processors:** URENCO Hanoi, the main actor for formal collection, is underfunded and does not provide an integrated and sufficient recycling solution; more than 90% of recyclable plastic waste in Hanoi is reliant on the informal sector with unstable labour and economic resources; collection for recycling is limited to high-value plastics and focuses more on urban districts.

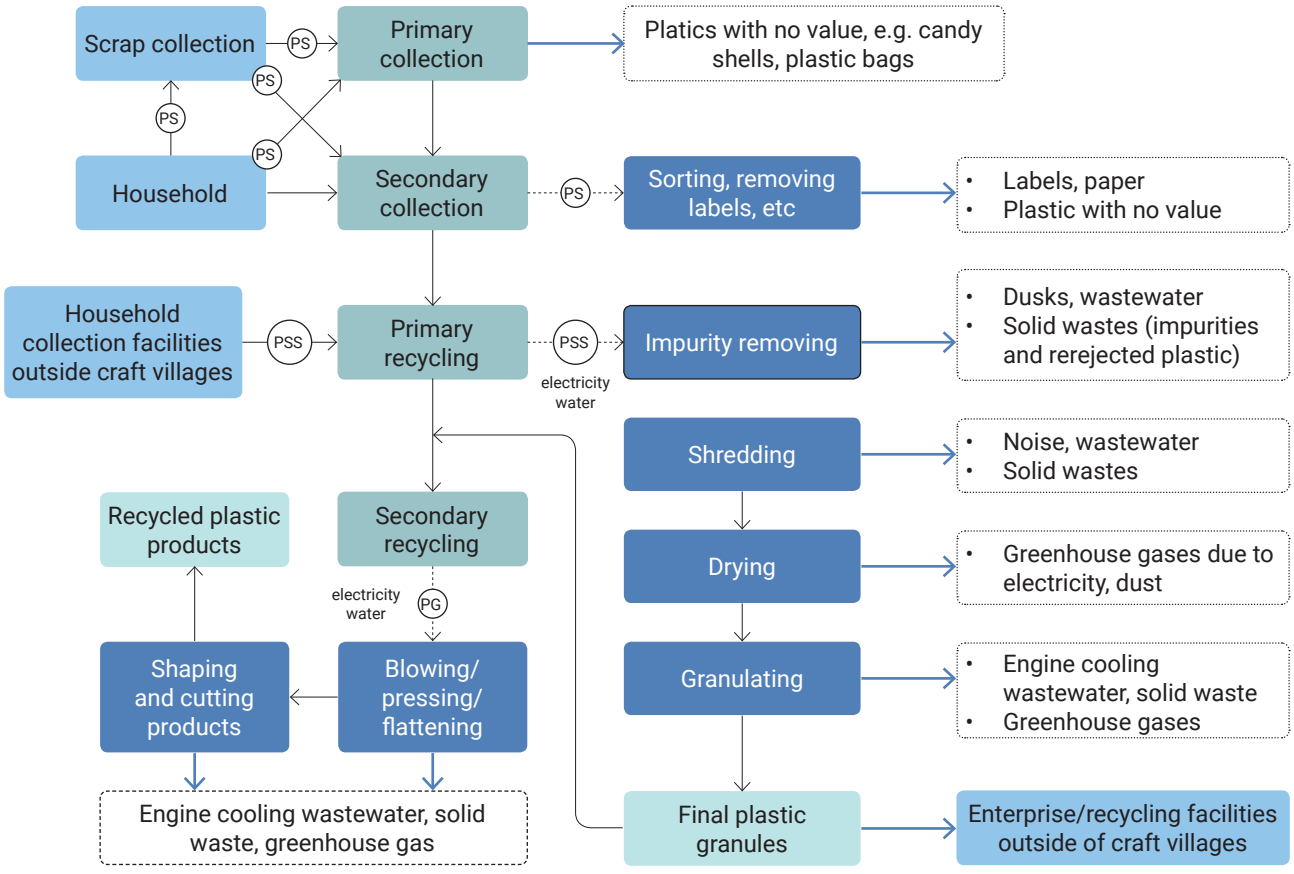
**Mechanical recyclers:** They face difficulty in obtaining a steady supply of high-quality recyclable feedstock owing to the opaque market structure, unstable input and output markets, and difficulties in obtaining green investment loans to equip advanced machinery and apply best available technologies (BAT) and best environmental practices (BEPs) initiatives.

Informal recyclers and craft villages typically operate as family businesses or small-scale enterprises that specialise in recycling discarded plastics or

other waste materials. Their operations are often constrained by limited production spaces, resulting in the inefficient use of raw materials and energy. In addition, awareness regarding environmental conservation during production processes is generally lacking. These enterprises face challenges related to low capital investment and financing because of their setup and operations. They primarily utilise intermediate plastic processing technologies and outdated machinery, and rely heavily on manual labour, resulting in suboptimal efficiency in material handling and production throughput.

The inadequate conditions of processing systems, coupled with the poor quality of recyclable plastic input materials, contribute to the accumulation of plastic waste and microplastics in discharged effluents. Most production facilities lack pollution control measures, waste treatment, and proper labour protection. Consequently, informal recycling and craft villages are associated with environmental pollution issues, particularly plastic pollution, resulting from their operations (Nguyen, 2020).

Effective management of residual waste from plastic recycling craft villages and factories is crucial for mitigating pollution from these enterprises. However, numerous recyclers have limited options for containing and treating MP-loaded effluents, often resorting to dumping or discharging them into drainage systems. Given Hanoi's susceptibility to urban flooding, poor waste management can exacerbate plastic pollution and facilitate the transport of plastic to waterways. For instance, densely populated districts such as Thanh Xuan, Hoang Mai, and Thanh Tri are drained by lakes such as To Lich, Lu, Set, and Kim Nguu, with numerous wastewater discharge points identified along these rivers. A study funded by the World Bank identified over 1,500 wastewater discharge




Notes: ⇢ Process of each stage; → Plastic leakage potential
PS = Plastic scrap; PSS = Plastic scrap after sorting; PG = Plastic granules

points along various rivers, including residential, industrial, and agricultural sources. Developing best practices for plastic recycling and industry, along with implementing remedial measures for spillage cleanup, is essential for minimising the environmental risks posed by micro- and macro-plastic pollution.

## 1.3 Objective

These guidelines aim to provide a framework for preventing recycling-related plastic and pellet losses, and environmental leakage. The guidelines are useful for a broad spectrum of stakeholders, particularly policymakers and key plastic recycling actors, including informal waste pickers, junkshops, consolidators, and plastic recycling craft villages. The application of these guidelines is expected to contribute to improving production efficiency in the plastic recycling chain while preventing plastic leakage into the environment.

# Section 2

# Preventing plastic losses and leakage from pre-processing

## 2.1 Plastic scrap generation

The preprocessing steps for plastic recycling involve storage, sorting, pre-cleaning, compression, baling, and sorting based on the polymer type and colour. In Hanoi, informal waste workers, junkshops, and aggregators primarily initiate preprocessing operations to recover post-consumer plastics for recycling. These entities, along with scrap dealers, enhance the value of plastic materials through preprocessing before they are transferred for mechanical recycling in craft villages. Craft recycling villages further sort, grade, and clean plastics to prepare them for mechanical processing, primarily by grouping them into polymer streams.

Owing to the specialisation of craft villages in Hanoi, the plastics received are often pre-sorted into similar material streams, thereby minimising sorting requirements. Recyclable materials purchased from industries typically require minimal sorting and cleaning. Certain processors may perform dismantling, sorting, and cleaning before processing, depending on the input material conditions and desired output. Managing losses during preprocessing is more feasible than managing smaller plastics that escape during processing. The processing stages involve steps such as flaking, crushing, grinding, sorting, washing, drying, and palletization, and water use increases the risk of loss and leakage. The plastic pellets produced were bagged, stored, and subjected to post-processing. Leakage issues vary between informal waste pickers and entities, such as junk shops and recyclers, with inadequate housekeeping practices contributing to losses and leakage during the intermediary stages.

## 2.2 Plastic scrap collection, classification, and transportation

### 2.2.1 Plastic waste pickers, collectors and aggregators

In the recycling value chain, post-consumer plastics undergo primary offsite sorting to improve the recycling standards from waste retrieval to mechanical processing. However, sorting efficiency and quality vary across different stages. Improving plastic recovery by waste pickers and buyers can reduce the amount of rejected materials, including non-recyclable polymers and contaminated items. Ensuring a steady supply of high-quality feedstock is vital for sustainable domestic recycling, and necessitates the inclusion of materials in recycling programs and sorting according to type to establish a viable recycling supply chain.

- The collected post-consumer plastics should be securely bagged and transported to prevent environmental loss.
- Recyclable plastic scrap and lightweight packaging can be transported in open carts and minitrucks.
- Small and lightweight plastic scraps and packaging should be bagged in PP woven sacks during transportation.
- PP woven sacks without perforations are suitable for bagging collected recyclable plastics because of their strength and light weight, which ensure durability during storage and transport.
- Therefore, the use of LDPE bags for transporting recyclable materials under extreme manual handling conditions is not recommended.
- Vehicles transporting recyclable plastic materials, including carts, minitrucks, and large trucks, must ensure proper containment to prevent spillages.

- PVC transport tarpaulins, canvas, or suitable cover nets should be used to secure plastic materials during transportation to recycling facilities, whenever possible.

### 2.2.2 Collection, storage and transportation

- Plastic scrap should be securely packaged in suitable bags to prevent spillage and contamination.
- The packaged plastic scraps should be stored in sheltered areas away from water sources and drainage channels to mitigate the risk of water damage and environmental pollution.
- Types of plastic scraps should be distinguished during storage for easier handling and processing in the subsequent stages of the recycling process.
- Pretreatment measures, such as pressing and baling, should be implemented to reduce the


Photo source: https://dantri.com.vn/doi-song/thu-phu-phe-lieu-lon-nhat-ha-noi-kho-nguoi-song-quay-nguoi-chet-20221103221818496.htm


Photo source: https://infonet.vietnamnet.vn/ha-noi-khoi-dot-nhua-doc-hai-am-khap-lang-thu-gom-phe-lieu-rac-chat-cao-nhu-nui-409383.html

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volume of plastic scraps, thereby minimising transportation and logistics costs while optimising storage space.

- The proportion of discarded plastics and residual waste generated during the pretreatment process should be minimised, emphasising efficient resource utilisation and waste reduction.
- Open burning of plastic waste should be avoided as it contributes to air pollution and poses health hazards to both humans and the environment.
- Discarded plastics should be transferred to specialised treatment facilities for proper and safe processing, ensuring compliance with environmental regulations, and promote sustainable waste management practices.
- Covers and other interventions should be applied to prevent the falling of plastic scrap during transportation
- Low-carbon vehicles or less pollutant and environment friendly fuel sources should be utilized.
- Vehicles that adhere to the transported weight/ volume and distance should be used.
- Sorting should be performed within factory premises to prevent contamination with dirt, oil, and dust.
- If the storage area is contaminated, pallets should be used when stacking the bales to limit excessive contamination.
- Measures to contain, collect, and properly dispose of rejected low-value polymers and other impurities should be implemented.
- Brooms, dust pans, and containers should be easily accessible to workers.

# Section 3

# Recycling processes

In Vietnam in general and Hanoi in particular, informal recyclers in scrap recycling villages mostly manufacture plastic granules from plastic scrap at the household scale. The diagram below illustrates a common plastic recycling process.

## 3.1 Material reception

Plastics such as shampoo bottles, shower gels, laundry detergents, food containers, and household appliances are collected and used as input materials (plastic scrap) for plastic recycling.

- ✔ Pre-sorted plastics should be placed on concrete floors
- ✔ Reception and storage should be in a designated clean and neat area; Do not place the material near light bulbs, cables, sockets, circuit breakers, electrical panels, or equipment at high temperatures. The minimum distance required for safety is 0.5 m.
- ✔ Materials entering/exiting the warehouse should be recorded and monitored in terms of volume, type, date of receipt/delivery, and source.
- ✔ Mechanisms for collecting and bagging rejects and low value plastics in super scraps sacks should be identified.

Popular plastic recycling processes in Vietnam

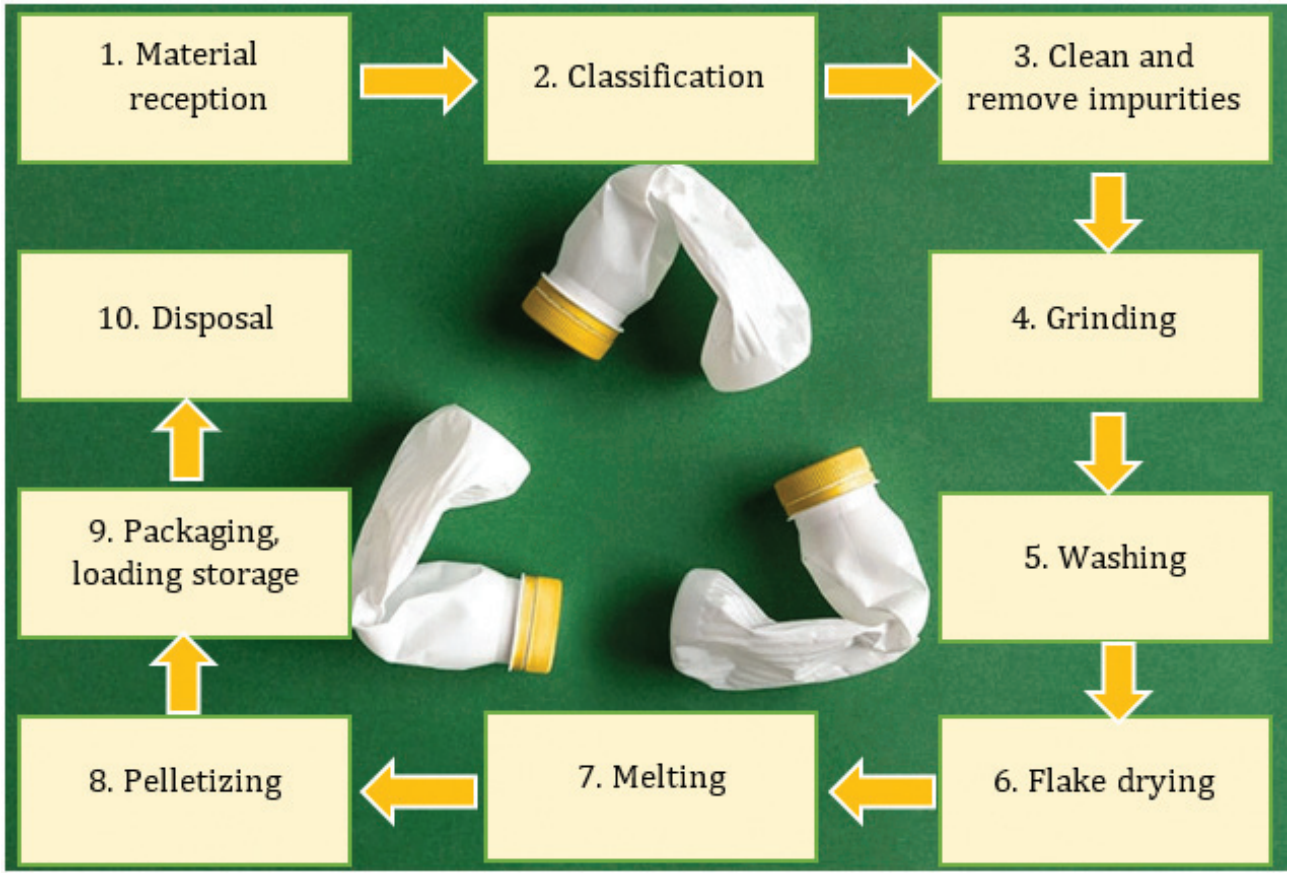


Photo source: Internet

Photo source: VNCPC's photo

- ✔ Transportation should be conducted in well-backed scraps sacks.
- ✔ All plastics are stored indoors or in sheltered areas.
- ✔ The warehouse should be equipped with fire prevention and fighting equipment and ventilation systems, have a high floor, an adequate drainage system to avoid flooding and rainwater entering, and better constructed walls, roofs, and partitions made of non-combustible materials.
- ✔ Fire prevention and fighting equipment (including fire extinguishers and sand for firefighting), emergency exit diagrams, and signboards indicating emergency exits should be established as directed by competent fire prevention and fighting agencies. These exits should be visible at all times to ensure that everyone exits the warehouse in the event of fire or another emergency.
- ✔ The location of the warehouse must have good ventilation, direct light should be avoided.
- ✔ Sufficient space for the quick and safe loading and unloading of materials from collection and transfer vehicles for handling or storage should be provided. The material storage space should be large enough to store for several days so that the line does not have to stop working because of a lack of materials.


Photo source: VNCPC's photo

- ✔ The storage, handling, and transfer of materials, equipment, and waste containers should be regularly checked to detect and immediately fix problems.
- ✔ All containers should be clearly labelled with necessary warnings and special handling instructions.
- ✔ The stack height of the individual containers/ drums must be limited and strapped or wrapped for stability.
- ✔ Fires should be prohibited, and cooking, burning incense, votive offerings, and smoking in raw material storage and production areas banned.

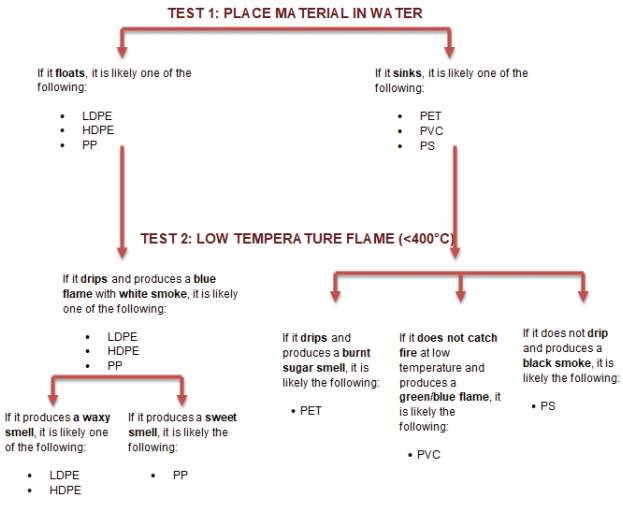
## 3.2 Classifications

Timely sorting and handling of plastic inputs helps prevent backlogs of materials that result in inefficient sorting and handling. Depending on the targeted recycled products, different types of plastic scraps are recognised and purchased by recyclers.

Two common classification methods have been developed by local informal recyclers.

**Common types of plastic and their uses.** (Photo source: Internet)

**Identify different types of plastic.** Source: Northstar Recycling




Currently, plastic sorting is performed manually at small-scale plastic recycling facilities. Plastic scrap is mainly sorted by female workers to remove impurities, such as tape, labels, glue, paper, metal, and glass.

✔ When sorting plastic scrap, workers should use labour protection (rubber gloves, masks, etc.) to avoid direct contact with sharp objects and other toxic chemicals/components mixed in the scrap plastic.

Photo source: Internet

✔ Installing conveyor belts can increase productivity by up to 30%, reduce labour during transportation, and improve worker health (reduce back pain) during sorting.

Photo source: Internet

✔ Efficiency in manual sorting should be improved: The owner of the recycling facility should develop a classification guide to help workers better identify plastics, avoid confusion, and classify practice materials using real-life illustrations. This method reduces impurities in the resin, thereby improving the overall process efficiency.

✔ Solid waste from sorting activities should be collected, stored, transported, and treated according to the law.

## 3.3 Clean and remove impurities

After sorting, the raw materials were cleaned. Depending on the plastic scrap, recycling households often use detergents (dishwashing liquids) or instal additional machines to separate the metal substances before shredding. To minimise wastewater and solid waste from material washing, recyclers should apply the following solutions:

Photo source: VNCPC's photo

✔ The amount of detergent appropriate for the number of ingredients should be determined,

biological detergents are used to replace the currently used dishwashing liquids to reduce the impact on the surface water environment.

- ✔ Additional stainless-steel nets should be installed along the washing tank to pick up small pieces of plastic before discharging them into the water stream to avoid the loss of raw materials and reduce plastic waste into the receiving water, such as rivers, streams, ponds, and lakes.
- ✔ The chopping and washing processes of raw materials should be optimised by reducing the water flow while ensuring product cleanliness by installing valves to limit the flow of water supplied to the chopper and washing tank.
- ✔ The amount of water used in accordance with the machine capacity and the input materials should be determined to ensure saving on water use.
- ✔ Additional wastewater treatment tank should be built: a two-compartment treatment tank to receive wastewater, including one settling chamber to separate large-sized residues such as soil, and sand mixed in scrap plastic; in addition, and one reaction compartment in the reaction compartment is filled with chemicals to raise flocculation and sedimentation aids to remove pigments and suspended residues. After treatment, water is pumped and circulated for use to reduce water use and wastewater.
- ✔ When charged for wastewater, households should calculate the appropriate amount of water to use and recirculate to reduce wastewater discharged into the environment.

## 3.4 Grinding

Shredding plastic scrap is a wet shredding process. This process generates noise, thus necessitating the following.

- ✔ Regular maintenance and monitoring of equipment, and placement balance breakers.
- ✔ Placement of the rubber piece under the four tripods of the machine.
- ✔ Processing of additional noise reducers, such as adding cover layers and closing the machine's soundproof box.

## 3.5 Washing

After chopping, the scrap plastic was washed. In this process, water is continuously pumped through a plastic pipe to clean the plastic scrap in the washing tank, using an agitator or a rotating barrel to remove impurities, sand, and unwanted materials from the plastic stream. After cleaning, the plastic was naturally dried before being transferred to the next stage of processing. This causes the granulation process to consume more electricity, because water remains in the plastic.

The purity of plastic scrap significantly affects the quality of materials and finished products. Moreover, the higher the purity of the plastic scrap before extrusion, the lower the number of filter discs/filters burned during the extrusion process to remove impurities from the plastic. This reduces the amount of harmful chemicals released into the environment.

During the process of washing raw materials, small pieces of plastic follow the wastewater stream and escape into the environment. These plastic pieces can clog water pipes and kill aquatic animals if swallowed. When the raw material is plastic containing detergents, oil, and chemicals, impurities and residues enter wastewater during the washing process.

**Washing tank** (Source: VNCPC's photo)

With a clean and homogenous source of raw materials, washing and cleaning during production (e.g. recycling trays for electronic components for Samsung) are unnecessary. After grinding, the plastic is directly transferred to the extrusion process.

To optimize this process, it is necessary to:

- ✔ Use the reverse wash option with the flaps
- ✔ Reuse hot water to cool plastic fibres to wash, thereby increasing washing efficiency
- ✔ Use natural surfactants to increase washing efficiency
- ✔ Increase the rinse time after washing by loading the resin through the waterspout
- ✔ Install a washing tank with a sludge removal screw at the bottom; the screw is responsible for removing sludge at the bottom of the washing tank without renewing the water. Sludge treatment should be carried out in line with regulations
- ✔ Install a rotating net in the wash tank to collect the small pieces of material that were not collected and transported by the vane.
- ✔ Install an anti-spill mechanism in the washing tank to aid in limiting the loss of water and materials and increasing the washing efficiency.
- ✔ Install additional nets or use cloth in the manhole to collect plastic pieces before wastewater is discharged into the environment.

Hanoi, Vietnam

Photo source: Internet

## 3.6 Flake drying

After washing, the plastic scraps contains a lot of water. This increases the power consumption of the extruder and reduces the quality of plastic.

- ✔ Waiting time for water flow out of plastic material before extrusion should be increased
- ✔ A screw dewatering machine should be used to remove the water, after which the raw material moisture content is reduced to 5–7%
- ✔ A drying system should be installed to remove water from the plastic, which helps reduce the energy consumption of the extruder and the amount of steam generated during extrusion, thereby reducing the working environment temperature and improving product quality.
- ✔ Using a high-pressure blower system to blow raw materials through the pipeline system in combination with hot air to dry the raw materials before transferring them to the extrusion stage to create granules; the material after drying had a moisture content of only 3–5%
- ✔ Drying naturally (under the sun) and applying measures to minimise the loss of plastic pieces (with tarpaulins, surrounding frames, and not near water sources)

Photo source: VNCPC's photos

## 3.7 Melting

The extruder is the main component that converts the milled plastic into strings through a mould. The screw was placed at the centre of the extruder using a heating element through its length. The heat used to melt the plastic scrap was controlled using a thermostat. The motor-driven screw conveyed the molten plastic to the opening of the mould.

Melting and extrusion of plastic was performed in two phases. The first extrusion was performed at 400ºC. The plastic, after being melted and filtered, was placed into the second extrusion machine (the temperature was approximately 230ºC in the beginning and 200ºC at the end of the extruder). The second extrusion was used to remove impurities such as sand and dust from the plastic by pressing it through the grit filter discs of the extruder, pulling it into long plastic strings, and cooling it in a water bath before chopping it into plastic granules.

The filter discs of the extruder were reused after burning to remove the impurities mixed with the plastic. Most extruders are not insulated, resulting in heat loss and more energy being expended to melt the plastic, which also increases the workplace temperature. These problems can be solved as follows.

- ✔ Adjust extruder temperature: depending on the melting temperature of the plastic, the extruder temperature can be adjusted to reduce energy use. By adjusting the extruder to operate at the right temperature, energy consumption is reduced by eliminating unnecessary heat.

- ✔ The filter should not be burned as it can potentially pollute the air. A cleaning solution should be applied using the automatic mesh change method without stopping the machine. Accordingly, impurities should be automatically removed from the mesh at the desired frequency during machine operation.

- ✔ Insulating the extruder to minimise heat loss, enhance extrusion efficiency, and ensure a safer working environment for workers.

- ✔ The use of an extruder that combines the 1st and 2nd extrusion stages into a compact and efficient machine is recommended. Compared to conventional machines, the combined extrusion system does not require workers to transport plastic between stages, thereby eliminating problems related to uneven feeding (over- or under-feeding).

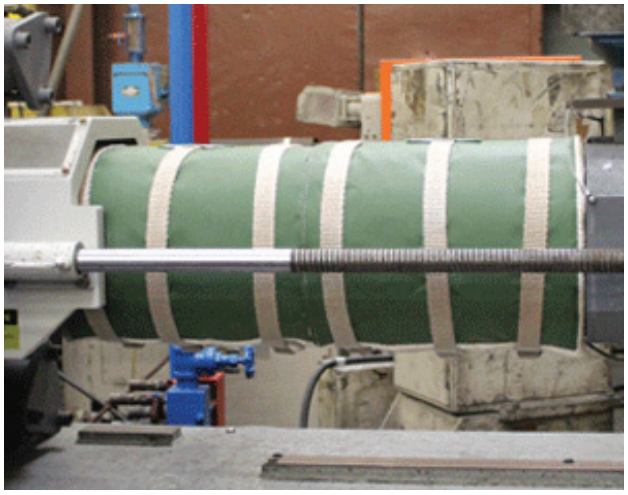
- ✔ The combined extruder has a full layer of insulation which saves energy owing to

heat loss. In addition, minimising heat loss improves the working environment, thereby increasing productivity and morale among workers.

- ✔ Installing a vacuum pump to recover hot air and steam to heat the washing water during the washing stage, thereby increasing the washing efficiency.

- ✔ Cooling water circulation: The water used to wash raw materials after cooling has a higher temperature than the water pumped from the bore well, which helps increase washing efficiency, leading to reduced water use and wastewater.

**Insulation layer is installed on the extruder barrel.** (Photo source: Internet)



## 3.8 Pelletizing

To harden them, the long and novel plastic strings are cooled in a water bath. The rotating blade shreds the plastic string. The sizes of the cutting particles can be adjusted by varying the rotational speed of the blade. A motor and gear system are used to rotate the blade during cutting. At the cutter head, the plastic strings are cut into pieces measuring approximately 2 mm into plastic granules as the final products.

Photo source: VNCPC's photo

- ✔ Suitable internal control measures are used to detect leaks and prevent spills, vibrating sieves are installed, and uniformly sized finished products, crumbs, or particles exceeding the standard size are removed.

**Vibrating sieves** (Photo source: VNCPC's photo)

- ✔ Hot water from plastic string cooling is reused as washing water to increase washing efficiency

- ✔ Cooling Towers are utilized for water reuse. This saves a copious amount of water and is widely used in industry. If the recycler does not want or cannot afford to purchase the tower, a simple alternative can be used to create a rain rig with a circulation pump to cool the water.

**Conventional cooling towers.** (Photo source: Internet)


Photo source: Internet

## 3.9 Packaging, loading storage and transport

After being cut into granules, plastic strings are cooled and packed according to customer requirements (usually 50-kg bags), placed on pallets for storage, and transported to the place of consumption.

- ✔ Using a silo system with a blower to temporarily store plastic pellets after production, when using a silo, has the following advantages: plastic pellets are drier and cooler; thus system improves convenience for workers in the process of packing products into bags, thereby increasing the efficiency of the packaging process.

Photo source: Internet

Photo source: VNCPC's photo

## 3.10. Disposal

### Incinerating

Waste treatment units use specialised incinerators with temperature ranges as high as 2000 to 3000oC[3]; at high temperatures, toxic substances are decomposed. In addition, incinerators use more waste gas treatment technology integrated into the furnace, thereby minimising the spread of harmful substances into the environment. Burning plastic waste at home or small gathering points is prevented, and a model of garbage collection to send to a unit specialising in incineration services is developed..

### Ultimate Recycling

Discarded plastics and waste can be recycled to produce useful products, such as pallets, bricks, tiles, board linings, and road pavements. The solution is suitable for numerous types of waste materials, such as discarded plastics, sand, and wood, and therefore does not require a high level of sorting of input materials. This technology has numerous advantages, including sustainability, environmental friendliness, and suitability for current circular economic trends.

### Sanitary landfill

A sanitary landfill is a simple, inexpensive, and final version of waste disposal without the purpose of recovering deposited materials. The main objective of sanitary landfilling is the safe disposal of waste, which is achieved by minimising the negative effects on the environment (e.g. from leachates, effluents of contaminated wastewater, discharge of air

3 https://anphatholdings.com/hoat-dong-moi-truong/xu-ly-rac-thai-nhua-dung-cach-giai-phap-giam-rac-thai-nhua.html

pollutants, and excessive emission of greenhouse gases). From the perspective of resource efficiency, landfilling is not the preferred option for any recovery process. However, the related direct operating costs are low, as are the requirements for the waste management systems.

Landfilling continues to be the preferred option for waste fractions that cannot be treated. This may apply to certain substances that are considered dangerous and for which alternative means of treatment (e.g. incineration) are not technically feasible. This also included remnants from incineration processes, such as ash, dust, and slag. Depending on the level of sanitary operations of the landfill and the social and environmental context, landfilling is generally environmentally preferred compared to other disposal practices, such as open burning or unsafe technical incineration.

# CONCLUSIONS

The technical guidelines in this document were developed based on field visits to plastic recycling craft villages in Hanoi, combined with the experiences of experts in plastic recycling, resource efficiency, and cleaner production. Some of the proposed solutions are simple and easy to implement with negligible investment costs; however, they have significant socioeconomic and environmental impacts.

Upon being widely distributed, the document is expected to serve as a "handbook" for informal plastic recycling facilities in Vietnam and other ASEAN nations (within the project's scope) to improve the efficiency of their production and business processes, thereby reducing the amount of plastic leaking into the ocean and supporting the move toward a circular economy.

The editorial team also hopes that, in the process of practical implementation along with the continuous development of the economy - science - technology, the guidelines and good practices herein will continually be updated to match the necessary context.