مـــوان MWAN
المركز الوطني لإدارة النفايات
National Center for Waste Management

الضوابط والأدلة الفنية
لتصميم مرافق إسترداد المواد وإنشائها وتشغيلها

Technical Guidelines
Design, Construction and Operation of Material Recovery Facilities

17 August 2023

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TABLE OF CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

LIST OF ACRONYMS

BAT	Best Available Techniques
CDW	Construction and Demolition Waste
EMS	Environmental Management System
HDPE	High-Density Polyethylene
IR	Implementing Regulations
MRF	Material Recovery Facility
KSA	Kingdom of Saudi Arabia
LDPE	Low-Density Polyethylene
MBT	Mechanical Biological Treatment
MSW	Municipal Solid Waste
MWAN	National Centre for Waste Management (The Centre)
NCEC	National Center of Environmental Compliance
NIR	Near Infrared
PET	Polyethylene Terephthalate
PPE	Personal protective equipment
TG	Technical Guideline
WM	Waste Management
WML	Waste Management Law

DEFINITIONS

Circular Economy	An economic model that aims at sustaining products and consumable sources for the longest period possible by way of consuming products to each product's maximum limit as long as it is usable, and to turn it recyclable and regeneratable thereafter upon the end of its lifecycle.
Competent Authority	The government entity responsible for operationally managing waste in accordance with a special regulatory provision.
Drainage	Natural or artificial removal of surface and subsurface water from an area, including surface streams and groundwater pathways.
Emission	The direct or indirect release of substances, vibrations, heat, or noise from individual or diffuse sources in the installation into the air, water, or land.
Hazardous Waste	Waste classified as hazardous based upon the provisions of the Law and Regulations, which is resulting from industrial or non-industrial activities that contain toxic, flammable, or reactive materials, or corrosives, solvents, degreasers, oils, colorants, paste residuals, acids, and alkalis.
The Minister	Minister of Environment, Water and Agriculture, and Chairman of the Board of Directors of the Centre.
Leachate	Solution obtained by leaching. The solution consists of liquid that, in passing through matter, extracts solutes, suspended solids or any other component of the material through which it has passed.
Inspectors	Persons designated by a decision of the Minister to take charge of detecting, proving, and investigating violations of the provisions of the Law and Regulation, jointly or individually.
Licence	A written permission issued by the Centre for the purpose of carrying out any activity related to waste management in accordance with the controls determined by the Law and Regulations.
Odour Management Plan	An odour management plan is part of the environmental management system (EMS) of the installation (facility) and includes elements to prevent or reduce odorous nuisances.
Permit	A document granted by the Centre to waste recycling facilities attesting that they fulfil the Centre's controls and requirements before they obtain the licences issued by the competent entities in accordance with their regulations.
Regulation	The Implementing Regulation of the Law.
Residues Management Plan	The residue management plan is a set of measures to optimize the production of residues generated by the treatment of waste, to optimize the reuse, regeneration, recycling and/or recovery of the residues and to establish the proper disposal of internal residues or waste.
Sensitive Receptors	Receptors that may be notably affected by the activity or the project due to its location being nearby or due to its sensitive nature, and these include without limitation: environmental components, living organisms, historical and cultural and religious sites, or social groups, such as endangered species, hospitals, retirement homes, schools, and residential compounds.
Sorting	It means separating waste components from each other manually or automatically, such as paper, glass, metals, and setting aside other components in transfer stations or sorting

	and treatment facilities; with the intent of recycling or processing them.
Storage	Storing the waste components or some of them temporarily for transfer or later use.
Treatment	It means the use of physical, biological or chemical means, or a combination of these means, or others to bring about a change in the specifications of waste in order to reduce its volume, or facilitate the processes of treating it when reusing or recycling, or extracting some products from it or to remove organic pollutants and others in order to reduce or utilize some of the waste components or eliminate the possibility of harm to humans or the environment.
Waste	All materials that are discarded or disposed of, and that directly or indirectly affect public health or the environment.
Waste Management	Organizing any activity or practice related to waste commencing from waste collection, transportation, sorting, storage, treatment, recycling, import, export, and safe disposal, including aftercare at waste disposal sites.
Waste Producer	Every person who produces classified waste according to the provisions of the Law.
Waste Service Provider	The person licensed or authorized to engage in one of the Waste Management activities.

1 PURPOSE AND SCOPE

1.1 Purpose

This Technical Guideline (TG) has been developed to provide a range of options and guidance on the selection of the best appropriate techniques and practices related to Material Recovery Facilities based on local KSA

economic, environmental, and social context. For the selection of the best option, the following criteria are taken into consideration:

- Sustainability of operations;
- Technical feasibility;
- Circular economy;
- Environmental Impacts & Risks; and
- Compliance with the new Waste Management Law (WML) and its Regulations.

1.2 Scope

Materials Recycling Facilities (MRFs), also known as Materials Recovery Facilities, Materials Reclamation Facilities, or Material Sorting Facilities, may be designed to handle mixed waste streams (internationally known as dirty MRF) or segregated individual/co-mingled fractions (or clean MRF).

This document is intended to provide technical guidance to all stakeholders with respect to clean MRF which treat source segregated waste. Activities include but are not limited to:

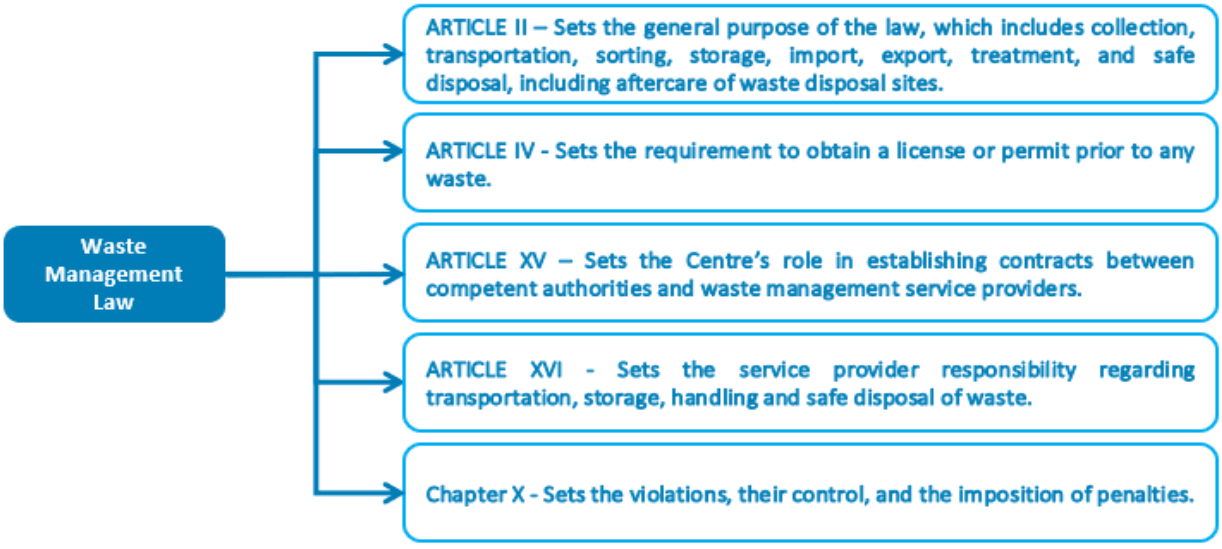
- Design, construction, and operation of MRFs;
- Environmental pollution along with health and safety prevention, reduction, and control measures;
- Proper management, recording and reporting of waste streams produced.

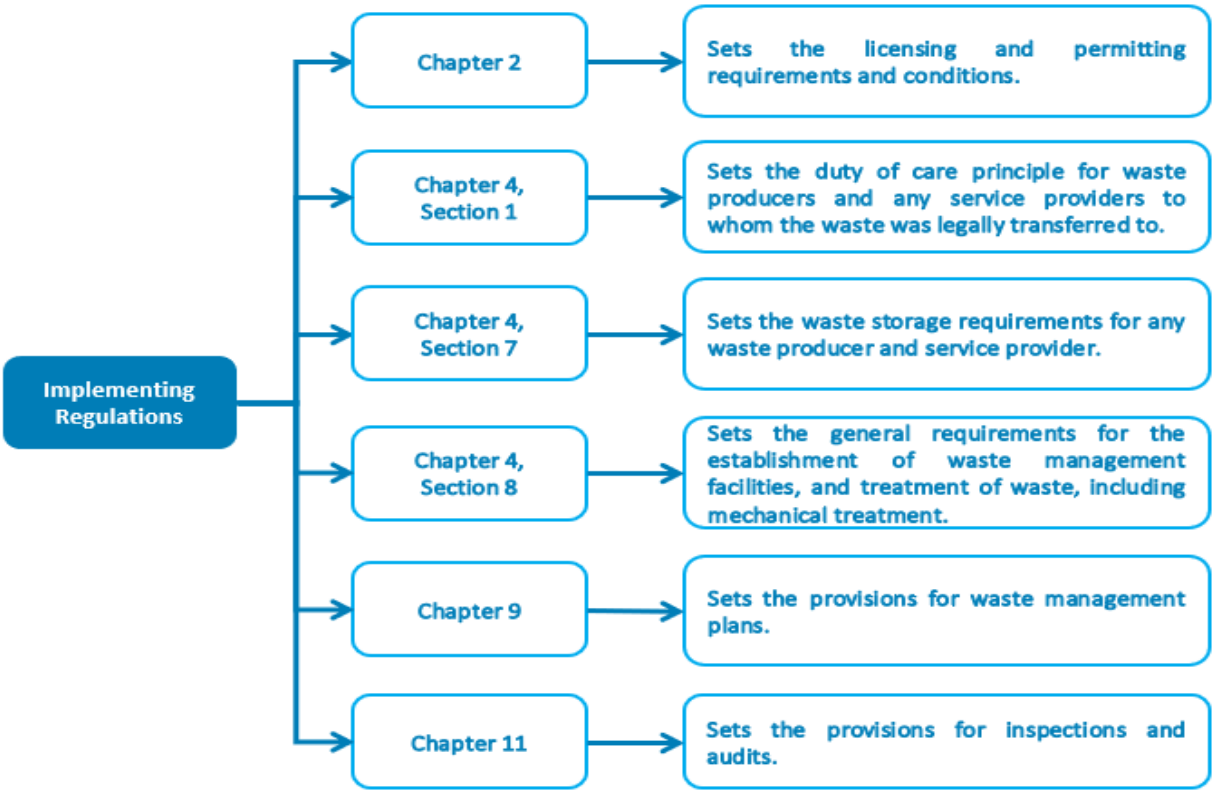
This technical guideline is not a design manual for MRFs and sound judgement, and the appropriate technical expertise needs to be applied to ensure that, when constructed, MRFs will comply with the principles set out here and with any conditions of a licence issued by the Centre.

Wastewater, radioactive, nuclear, or military wastes are not included in the scope of the mandate of the National Center for Waste Management and accordingly, are also not included in the scope of this document.

2 Legal Requirements

The Technical Guideline on Establishment and Operation of Material Recovery Facilities complements the information provided by the Waste Management Law and the corresponding Implementing Regulations, with a more structured approach to guide users through the process of establishing and operating a Material Recovery Facility (MRF). For legal requirements on MRFs, however, users are advised to consult both the WML and the IR. The main legal provisions on inspections and audits are highlighted below.





Chapter 4, Section 8 of the Implementing Regulations details several requirements regarding waste treatment, with articles 118 to 127 providing the requirements for mechanical treatment of waste, as follows:

- **Article 118 –** Displays a variety of technologies included under mechanical treatment of waste;
- **Article 120 –** Details the minimum requirements that a mechanical waste treatment facility should follow in order to get approval by the Centre;
- **Article 121 –** Sets the requirements for any mechanical waste treatment facility to identify relevant environmental controls, contingency plans, and emergency response plans;
- **Article 123 –** Sets the requirements related to the facility workers' qualifications and non-personnel movement control;
- **Article 124 –** Details the temporary waste storage requirements prior to sorting;
- **Article 125 –** Sets the data recording and reporting requirements;
- **Article 126 –** Details the circumstances under which incoming waste may be rejected by mechanical waste treatment facilities.

3 Roles and Responsibilities

This Technical Guideline is addressed particularly to the stakeholders involved in the establishment and operation of material recovery facilities, including also relevant provisions to other stakeholders in different stages of waste management that may use material recovery facilities.

The Roles and Responsibilities of the entities involved are listed below.

Ministry of Environment, Water and Agriculture (MEWA)

- Sponsoring department in KSA government for MWAN, has overall responsibility for Environment and Waste management
- Policy maker for the sector
- Sets the overall direction for waste management

MWAN – The National Centre for Waste Management

- Regulate the waste management sector
- Issue licenses and permits for Service Providers, and monitor their operations
- Carry out inspections to assess compliance with laws and regulations
- Collect and process data reports from waste generators and service providers

Waste Producers

- Identify and classify waste at source
- Ensure proper segregation and storage of waste
- Contract only licensed service providers for the proposed activities
- Ensure proper use of the manifest
- Report data accurately and timely, according with the established controls

Service Providers of Mechanical Treatment

- Obtain the proper license according to the proposed activities
- Ensure full compliance with license terms and conditions
- Ensure that waste is duly processed according to the existing contract and the regulations
- Report data accurately and timely, according with the established controls

4 Overview on MRF

4.1 General Considerations

Efficient and proper waste management is an essential part of the transition to a circular economy and is based on the "waste hierarchy" which sets the following priority order: prevention, (preparing for) reuse, recycling, recovery and, as the least preferred option, disposal.

In order to fully take the most out of each waste material, it's essential that waste is separated between different components, as each stream will have different considerations and requirements in order to be reused, recycled, or recovered. The basic reasons for segregating waste are:

- to facilitate the processing of the waste higher in the waste hierarchy;
- to recover inherent resources and material;
- to reduce the amount of waste which has to be sent for disposal; and

to transform the waste into a useful material.

Material recovery from waste is the act of separating and processing waste streams in order to take the most value out of each. Ideally, material recovery will start at place of generation, whether it is households, commercial institutions, offices, or industries, by segregating waste into recyclables and non-recyclable waste, thus preventing contaminations, and retaining the highest value for each material.

Material Recovery Facilities can be described as infrastructures that accept waste materials, either source segregated or mixed, and further separates, processes, and stores for further processing, in order to divert reusable and recoverable waste from landfill, while also obtaining the maximum value out of each material. While no two MRFs are identical, even the ones processing the same materials, they usually employ common operational principles and sequencing of the equipment and labour. Figure *4-1* below summarizes the most common waste processing sequence at an MRF.

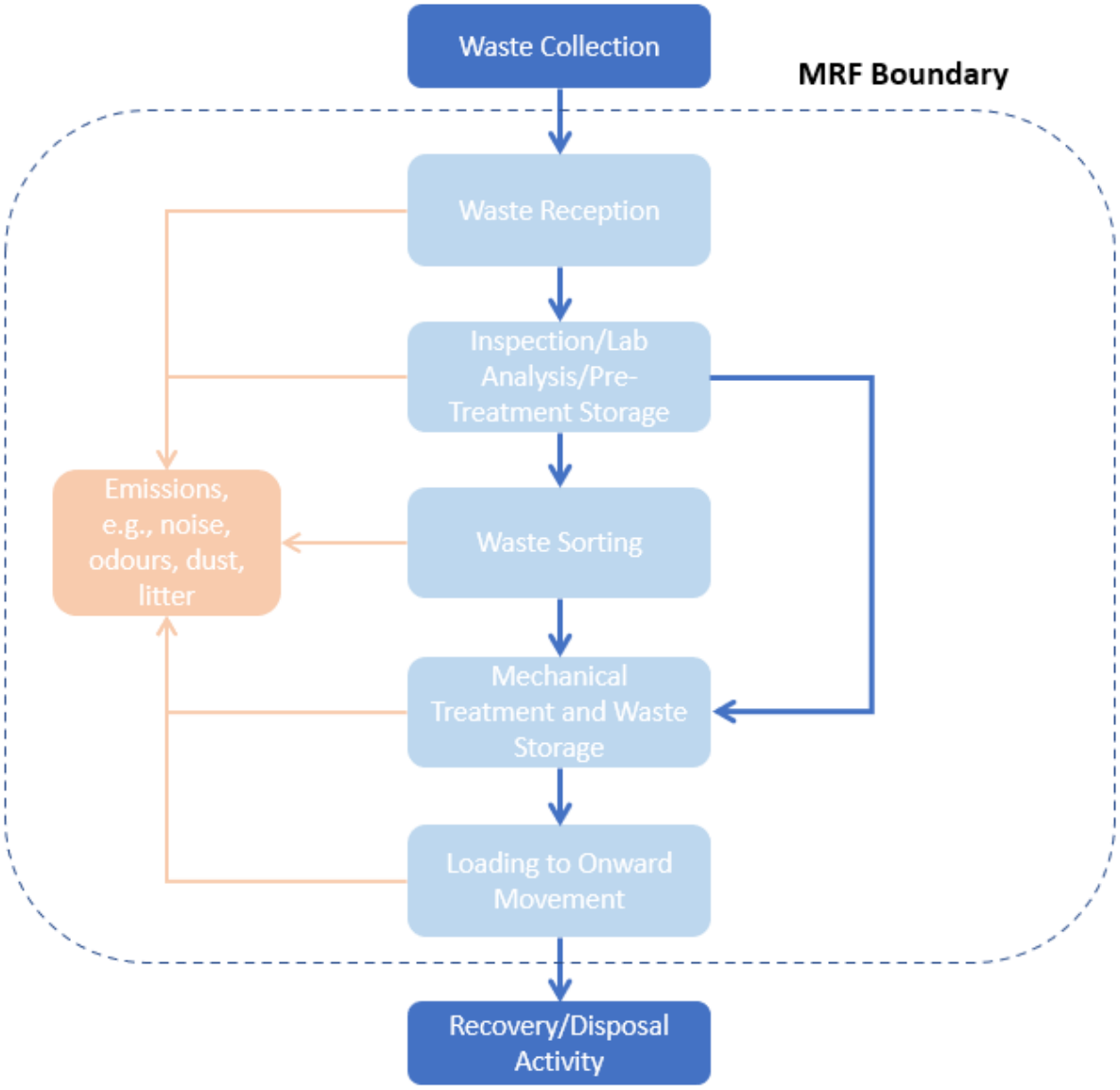


Figure 4-1: General waste processing sequence at a MRF

Generally, a solid waste management system typically comprises a few different components, from waste segregation, collection, storage, treatment to finally disposal. MRFs are usually involved in the middle of this system, as displayed in Figure *4-1*, regarding processing and treatment and some level of storage. Not being involved in the segregation and collection stages of the system leads to a lack of control regarding the quality of the input waste, leaving MRFs vulnerable, in a way, to the municipality's approach (or any other entity responsible for the management of the waste) on segregation and collection of waste. Whenever feasible, stakeholders responsible for the establishment and operation of a MRF should settle with the waste management entities in the area, levels of effort to ensure that all land uses are receiving adequate conditions to source segregate waste (i.e., number of bins, bin locations, etc).

Additionally, MRF operators should also promote public awareness campaigns to the extent of their possibilities, in alignment with the municipality and/or other waste management companies, to properly educate and incentivize the population to accurately segregate the waste according with the established segregation system, and through a variety of sources, as displayed in Figure *4-2*.

Figure 4-2: Public awareness strategy examples.

In addition to a variable input stream, both in composition and quantity, MRFs also face varying revenue streams, not only related to the aforementioned issue, but also due to volatile commodity prices. Typically, after waste is sorted it will be sent to a broker, another processing facility which will further prepare the items for remanufacturing, or to mills or other companies to be used directly in manufacturing processes. Establishing agreements on material quality, quantities, and even processing methods (such as baling) with clients can lead to more stable and uniform facility operations. Additionally, establishing sale agreements based on fixed volumes can help to secure the MRFs operations, even when demand or commodity prices decrease.

4.2 Types of MRF

Several different types of MRF exist, focusing on different types of waste. Most commonly, Material Recycling Facilities are used to process Municipal Solid Waste (MSW) including household waste and administrative and commercial waste, either mixed or separately collected waste (dry recyclable fraction comingled or not), but

other facilities dealing with different waste streams such as Construction and Demolition Waste (CDW) also exist. This document focuses on detailing the establishment and operation stages of clean MRFs, which is a type of MRF that processes recyclable waste from MSW. Dirty MRFs also process MSW but include residual waste. A brief description of each is displayed below.

4.2.1 Clean MRF

A clean MRF is a facility that only processes recyclable waste, mostly from residential or commercial areas, either source segregated or as mixed dry recyclables. They are most commonly established in proximity of cities or communities where a high degree of source segregation is implemented, as this leads to a stable supply of recyclable material with lower degree of contamination. This type of facility should be a core part of any waste segregation strategy, as a complement to the source segregation and a way to ensure consistent high quality material retrieval.

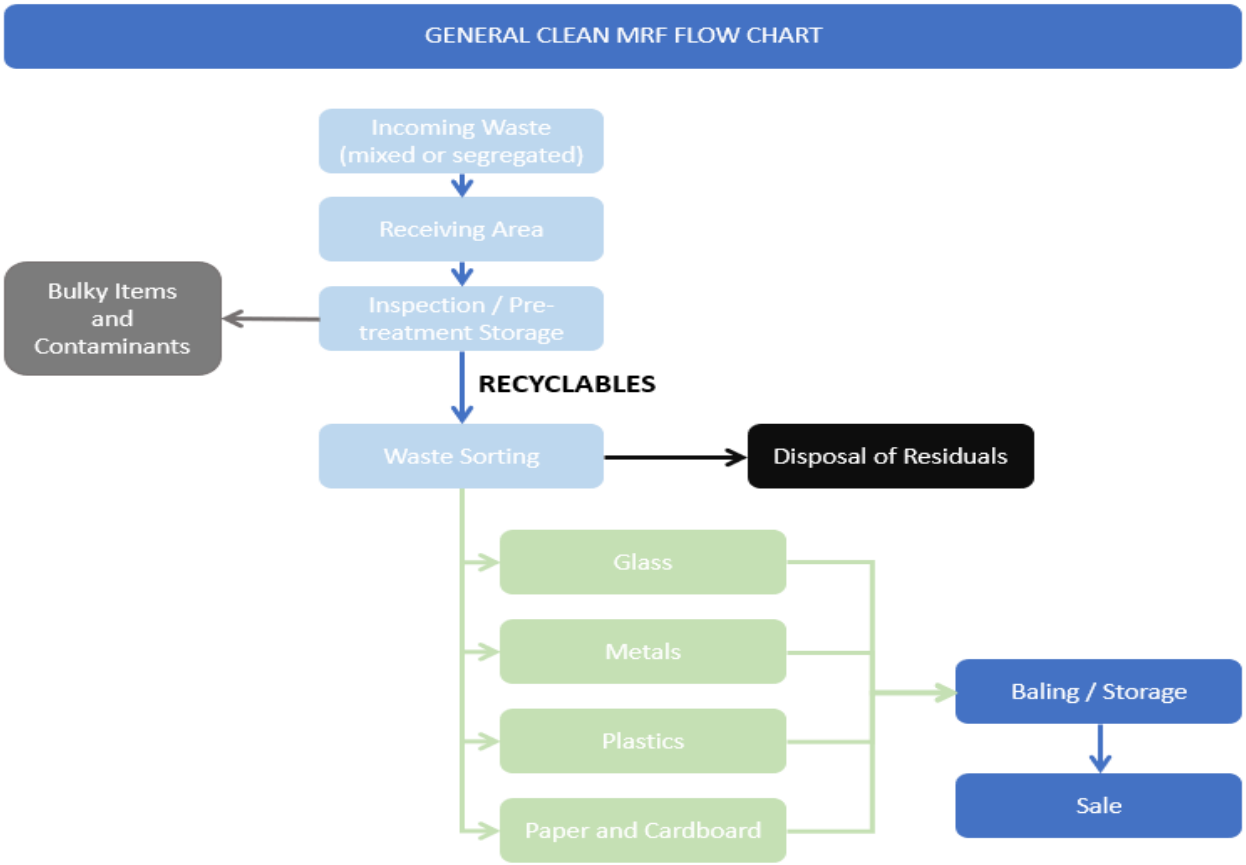


Figure 4-3: Clean MRF waste processing sequence.

Typically, clean MRFs have a high waste recovery rate, meaning that out of all the waste entering the facility, a significant amount will be separated from the main load and sent to recycling and recovery facilities for further processing, while only a small amount will be left as residual waste that will, in most cases, be either incinerated or landfilled.

4.2.2 Dirty MRF

Dirty MRFs process residual waste, mostly from residential and commercial areas, in an attempt to capture recyclable materials that have been included in the residuals bin, hoping to retrieve some value of a waste

stream that would, in most cases, be incinerated or landfilled. For the most part, the materials recovered from a dirty MRF are similar to the ones recovered in a clean MRF, although typically more contaminated by organic and other residual waste. This issue can be relevant for all the materials recovered, but is particularly significant for paper and cardboard, as the contamination with organic matter can render its future recoverability not feasible.

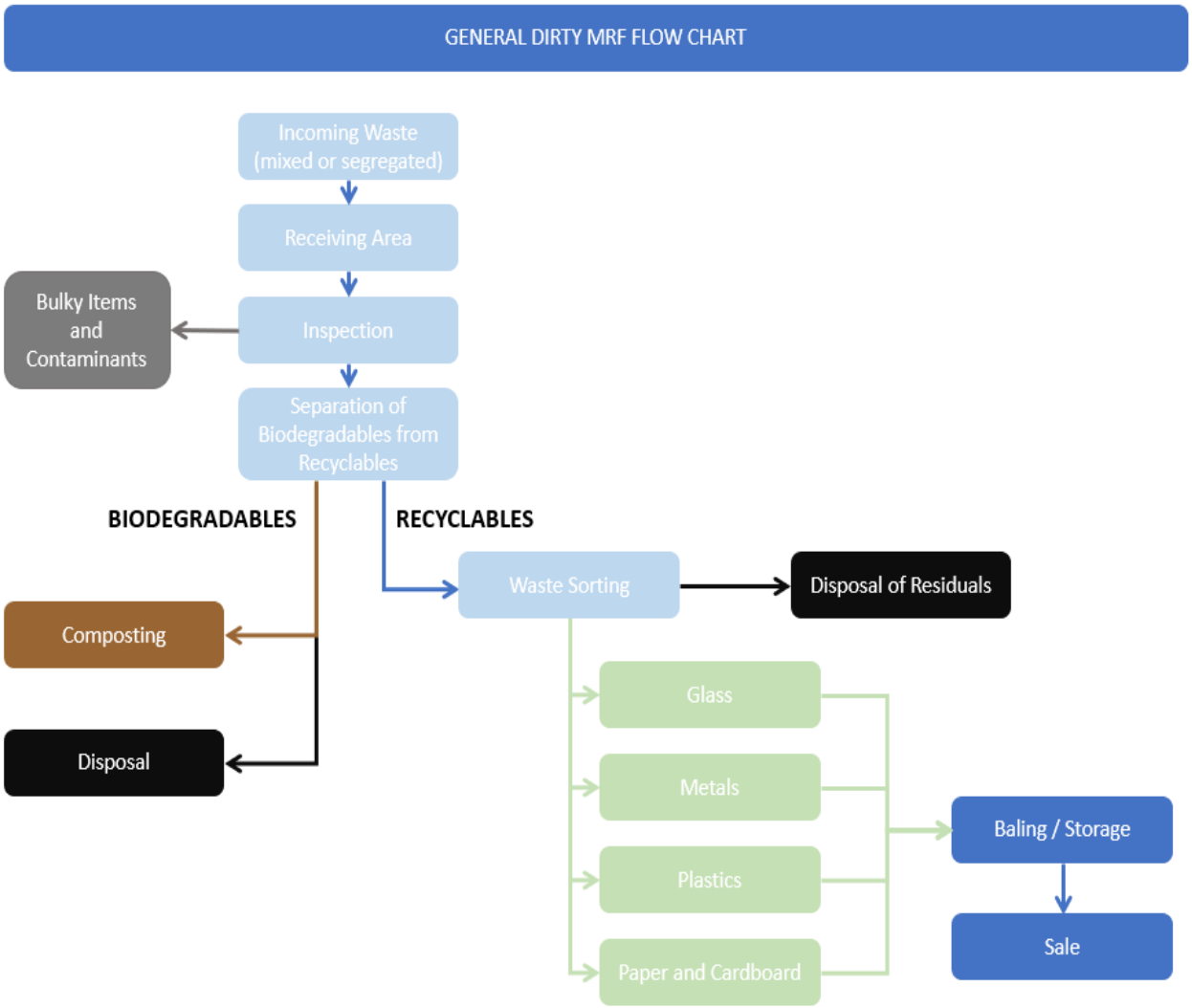


Figure 4-4: Dirty MRF waste processing sequence

Dirty MRFs are usually significantly less efficient at retrieving recyclable materials when compared to clean MRFs, as the mixture of organic and other residual waste combined with the recyclables may render them hard to distinguish and sort, both manually and by automated equipment, or even lead to its deterioration and therefore non-recoverability.

In addition to clean and dirty MRFs, a third type of MRF is also frequently considered, called wet MRF. This facility is essentially a dirty MRF which uses water to separate and clean the streams being processed, and in some cases, begin to biodegrade certain organic components.

Dirty MRFs are similar in technology to MBTs which are already being addressed under a specific Technical Guideline. As such, dirty MRFs are only briefly described under this section, and for further reference, the Technical Guideline on Mechanical and Biological Treatment should be consulted.

5 Site Specifications and Infrastructure

5.1 Siting – General Considerations

The selection of a location to establish a MRF will have to consider a number of factors involving not only operational requirements, but also its impact in sensitive receptors in the vicinity resulting from its operations. Article 95 of the Implementing Regulations details several provisions to consider when choosing a site for the construction and operation of a waste management facility, which includes the following factors:

- The distance between the suggested site and the production, collection, and storage of Waste locations;
- Availability of infrastructure and paths for facilitating the arrival to the location in all seasons, and the impact of the facility on the traffic at that area;
- Keeping away from historical sites and reserves;
- That the area has suitable capacity for all generated wastes throughout the facility's lifecycle;
- Avoidance of sites on very steep locations, as level grounds are preferrable;
- That the site is distant from valleys, reefs, flood streams, beaches, bodies of water and water sources, such that it does not pollute any water source;
- That the site is not in areas where the groundwater percentage is high, or in sabkhas;
- the dominant direction and speed of the winds, such that the facility must be located in the opposite direction from the wind direction in that area;
- That the site is distant from currently used lands or the lands that are planned for development purposes, such as urbanized, commercial, agricultural, or industrial areas;
- In case of choosing a location for a landfill, the suitable and fulfilling soil must be existent to cover the waste, taking into consideration that the soil has low permeability and coherence;
- That the site is as far as possible from any masts, electric lines, railways, airports, facilities' pipelines, and highways.

Any additional provisions that could affect the area's capacity to receive a facility should also be considered, including any controls or requirements the Centre issues. These constraints should be made clear through a site investigation.

Article 97 of the Implementing Regulations further adds considerations regarding the site and area selection, detailing the locations in which it's forbidden to build a facility, namely:

- Sites adjacent to planned land for development purposes such as urban, commercial, and agricultural expansion areas;
- Sites within the area of villages or seaside areas, or flood streams, where the treatment and disposal of waste may expose the water to contamination, as a result of leakage of fluids to the ground;
- Sites with high groundwater attributed, especially in areas where this water is used for agriculture or drinking;
- Sites on very steep locations;
- Sites on historical archaeological or natural areas or environmental reserves;
- Areas adjacent to airports and subject to the classification of the General Authority of Civil Aviation;
- Any other area deemed by the competent authorities as invalid for the establishment of a facility for the treatment and disposal of waste.

5.2 Surface Water Drainage

Surface water caused by run off of entrained water from the waste mass and storm water drainage are collected and managed separately. Contaminated water is transferred to a treatment unit while storm water runoff is disposed on to a natural recipient.

The design of the drainage system must be taken into account pre-development. The drainage systems must be inspected at annual intervals throughout the operational life of the facility to ensure their integrity.

5.3 Utilities and Facilities

In order to ensure the health and safety of on-site personnel, and to enable control of operations on site the following utilities and facilities in combination with the appropriate equipment must be provided at all MRFs[1]:

- Water supply:
  - Sufficient drinking and non-potable water, with separate distribution networks;
  - Water pumping station.

- Power supply:
  - Distribution substations at strategic locations, with network of underground cables or overhead lines.

- Street lighting:
  - Conventional or solar street lighting;
  - Smart energy-efficient lighting.

- Sewerage:
  - Sewage and effluent collection and storage systems;
  - Systems for removal of contaminants from wastewater, and storm run-off through primary treatment of effluents;
  - Treated and recycled water distribution system.

- IT connectivity, telecommunication, and ICT-enabled resident services:
  - High-speed Wi-Fi and internet services;
  - Robust data infrastructure system;
  - Communication system within the MRF plant.

[1] (United Nations Industrial Development Organization, INTERNATIONAL GUIDELINES FOR INDUSTRIAL PARKS, 2019)

- Safety and security:
  - Health care centre, medical facilities;
  - Emergency response centre/s (including for accidents and first aid, fire, and chemical hazards, security incidents, natural disasters, and crises, etc.);
  - Public safety infrastructure, including lighting and CCTV surveillance systems.

5.4 Fencing and Security

The site should be fenced, and barriers should be placed around the property in order to control site access for non-authorized personnel, both for operational and liability issues. Fences must be a minimum of 2 meters tall around the entire perimeter of the site. Appropriate signage to discourage trespassers must be erected at the site entrance. If performed properly, fencing could additionally ensure protection from pests such as rodents and also other animals, reduce littering, increase security and reduce operational constraints.

Other provisions for security purposes may be considered such as CCTV system, nighttime lighting, and security staff, in order to discourage scavenging and improper disposal of waste in the vicinity.

5.5 Waste Rejects Area

An area of the site must be made available to allow for the temporary segregation of suspect or unacceptable waste loads, which enter the site. This area should be located away from the main areas frequented by personnel.

This area must be clearly marked with reference to its required purpose to ensure that there is no inadvertent mixing of waste materials.

5.6 Licensing

Facilities operating in the field of segregation, preparation, storing and trading of recyclable materials must submit an electronic application to the Center in order to obtain the appropriate permit/license. For further information, the Implementing Regulations should be consulted, along with the Technical Guideline on Authorisation and Licensing of Activities and Facilities.

6 Design Requirements

6.1 General Provisions

Establishing a MRF is a complex task that requires not only considering the purpose of the facility, but also the surrounding areas, the existing and planned waste management systems, along with several different constraints specific for every situation. Table *6-1* displays some of the key considerations and the respective design issues to keep in mind when designing a MRF.

Table 6-1: Key considerations and design issues when planning a MRF.

Consideration	Design Issue
Facility Location	Location of facility in relation to sensitive receptors; road network; adjacent premises; proximity to waste capture areas
Type of Facility	Land requirements; layout; site services
Nature and Quantity of Waste	Environmental control measures; present and future storage requirements
Nuisance Control	Capture, containment and/or treatment of odours, dust, litter
Water Control	Rainfall; surface water run-off; groundwater protection; containment; flooding risks
Emergency Planning	Protection of sensitive receptors; preparation, review and testing of emergency plans, equipment and facilities
Visual Appearance	Landscaping and visual aspect

Clean MRFs, particularly, focus on recyclable waste and are not prepared to deal with large quantities of organic waste and other contaminants. Therefore, establishing such a facility near a community where no source segregation is taking place would result in a lack of quality input material and severely hinder its feasibility. The opposite scenario can also be true and the establishment of a clean MRF near a community where waste is source segregated into multiple streams should be followed by an adaptation of the MRFs' processes and equipment in order to, for example, have dedicated lines to process source segregated recyclables instead of a single line processing commingled recyclables, as the recovery rates could vary significantly.

The nature of the waste generators in the facility vicinity should also be considered when planning for a MRF in order to account for the different amounts and types of waste expected. Even when considering the same materials, residential areas usually dispose mostly of some specific types of waste, while commercial areas, offices and industrial areas dispose of others. Considering these differences will lead to a fit for purpose facility, fully prepared to deal with the incoming waste. Table *6-2* details some of the main types of recyclable waste expected for each land use.

Table 6-2: Most common recyclable materials from each land use.

Land Use	Material	Most Common Recyclable Waste
Residential Areas	Plastic and Metal	Plastics bottles; cans; plastic containers
	Paper and Cardboard	Newspaper; packaging cardboard
	Glass	Glass bottles; glass containers
Commercial and F&B Areas	Plastic and Metal	Plastics bottles; cans; plastic containers
	Paper and Cardboard	Newspaper; packaging cardboard
	Glass	Glass bottles
Offices, Industries, Institutional Areas	Plastic and Metal	Plastics bottles
	Paper and Cardboard	Office paper; old corrugated cardboard

6.2 Types of MRF

In addition to the classification of MRFs according to the type of waste processed, having clean MRF for recyclable waste and dirty MRF for mixed residual waste, MRFs can also be classified according to the level of automation of processes within the facility. Following this arrangement, MRFs are usually classified into one of three categories:

- Manual MRF;
- Semi-automated MRF; and
- Automated MRF.

As the names suggest, manual MRFs will work exclusively on manpower, while semi-automated MRFs will use varying levels of automated equipment combined with manual labor to process the waste, and automatic MRFs will have a fully automated waste processing sequence. Figure 6-1 to Figure *6-3* below provide a brief description and schematic representation of each type of MRF.

Manual MRFs use manual labor to separate the different components of the waste. This method of processing is usually slower than automated processing, for which reason it applies mostly to MRFs with very low capacity.

Figure 6-1: Manual waste sorting.

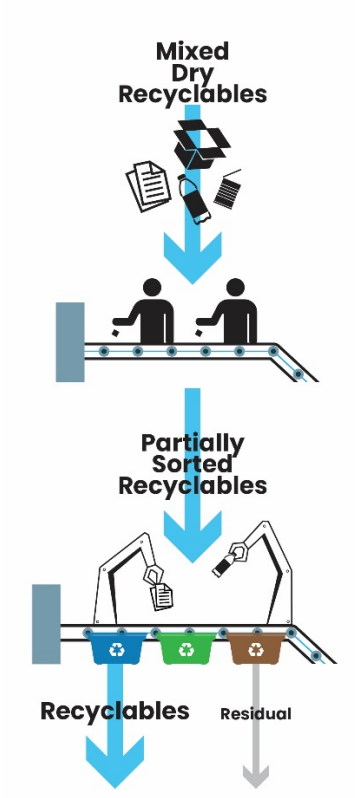


Figure 6-2: Semi-automated waste sorting.

Semi-automated MRFs are the most common approach to sorting plants, as they use a combination of manual and automated sorting techniques. Typically, manual processes are either at the beginning (to remove bulky waste and contaminants) or at the end of the sorting sequence, mostly for quality control of the process.

Automated MRFs use a large variety of mechanized equipment to automatically process the waste into the different categories. This type of facility is more expensive, but can usually achieve larger processing rates, thus being a more common approach in areas where very large quantities of waste are expected.

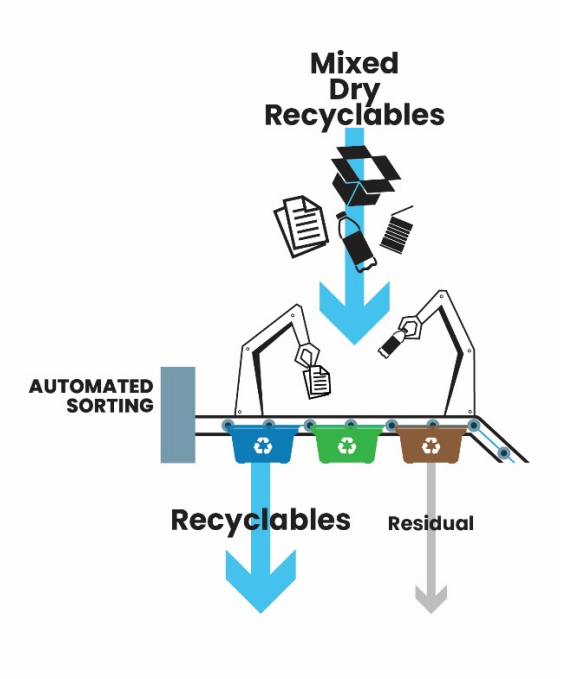


Figure 6-3: Automated waste sorting.

6.3 Facility Equipment and Design

A typical MRF is located in an enclosed, covered facility, with concrete flooring and a perimeter fence for security. These facilities should be designed considering provisions for washing equipment along with floors and walls frequently, ensuring that all wastewater generated is properly and efficiently managed. The facility design should also minimize the placement of columns that could interfere with the efficient movement of materials and equipment, and design ceilings with sufficient height for the expected daily operations. Regarding the areas available in the facility, at a minimum, it usually includes the following:

- Receiving and/or tipping area;
- Sorting/processing area;
- Storage area for recyclables;
- Storage area for residuals; and
- Loading area for residuals and processed recyclables.

In addition to the above, MRFs should also include the usual areas for any industrial type of facility such as equipment storage, offices, staff commodities, among others. As much as possible, areas should be designed adjacent to one another in a way that minimizes waste movement.

The most basic type of equipment present at a MRF are conveyors and material handling equipment required to move the waste throughout the facility, screening and sorting equipment that will separate the different materials according to set characteristics, and then mechanical processing equipment that will turn the

sorted waste into pieces easier to store and transport. The actual equipment to use will be highly dependent on target capacity, nature and composition of incoming waste, intended destination of processed waste, among others, but a general description of the most common equipment is displayed below in Sections 6.3.1 to 6.3.5[2].

6.3.1 Receiving/Tipping Area

The tipping area at a MRF is simultaneously the reception area and the preliminary storage area, where waste will be tipped into and stored until it is sent for processing. This area should be designed taking into account the number of different streams to receive, meaning that commingled waste would all be tipped into one area, and source segregated recyclables should remain separated and be tipped into individual areas. Additionally, the reception area should be protected from the weather, as water can significantly reduce the value of some recyclables, particularly paper and cardboard, and lead to leachates for others, and should be designed with sufficient capacity to store at least two days' worth of incoming waste, allowing for some operational margin considering unscheduled equipment maintenance or high demand periods. Large tipping areas provide not only easier manoeuvrability for trucks and other vehicles, but also a buffer for future adaptations to the system such as an increase in the number of waste streams received at the facility.

Typical equipment included in this area of the facility is:

Weighbridge[3]

- Truck weighing equipment for incoming loads.

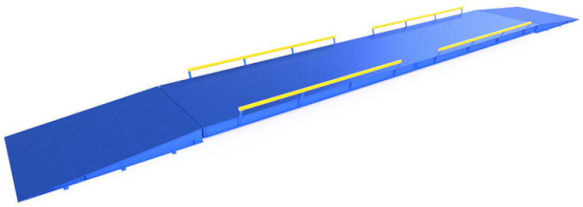


Figure 6-4: Weighbridge example.

[2] **Disclaimer:** The images used in these sections are meant for illustrative purposes only. They do not represent the Centre's judgement regarding the best available equipment, technologies, nor manufacturers and suppliers.
[3] Image used for illustrative purposes only. Taken from Libraweighing's online page.

Weighing Scales[4]

- Scales to weigh smaller quantities of incoming waste;
- May be applicable only if receiving waste from individual or small-scale suppliers.

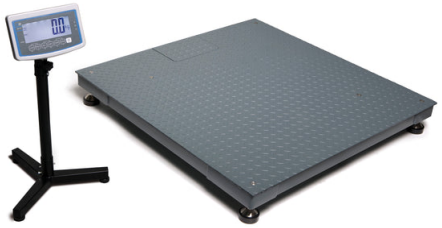


Figure 6-5: Weighing scale example.

Waste Loader[5]

- Commonly used vehicle to load the waste from the tipping area into the processing section.

Figure 6-6: Waste loader example.

6.3.2 Sorting/Processing Area

MRFs are designed to process heterogeneous waste and separate it into different materials that are clean and possess high market value and recyclability. The efficiency of this process is highly reliant on several considerations which will determine the MRF's feasibility. The equipment to be used is one of the most relevant aspects, and a general description of the most common processing equipment to use in a MRF is displayed below.

It should be noted that the equipment images displayed below are just provided as an example and may not reflect industry's most recent or more feasible equipment.

6.3.2.1 Waste Transport

Belt Conveyor[6]

[4] Image used for illustrative purposes only. Taken from Meltrons' online page.
[5] Image used for illustrative purposes only. Taken from Peterson Cat's online page.

- Main equipment to transport waste across the facility;
- Connects all the sections of the sorting process.

Figure 6-7: Belt conveyor example.

6.3.2.2 Waste Screening

Trommel Screens[7]

- Rotating device with holes that separates waste based on size. Small objects and debris fall through the holes, while larger objects reach the end of the machine.

Figure 6-8: Trommel screen example.

Disc/Star Screens[8]

[6] Image used for illustrative purposes only. Taken from CITConveyors' online page.
[7] Image used for illustrative purposes only. Taken from West Salem Machinery's online page.
[8] Image used for illustrative purposes only. Taken from Environmental Expert's online page.

- Similar to trommel screens, disc/star screens separate larger materials from smaller items through a set of rotating discs. Smaller objects fall through, while larger objects are transported to the end of the system. Typically, only trommel or disc/star screens are used, not both.

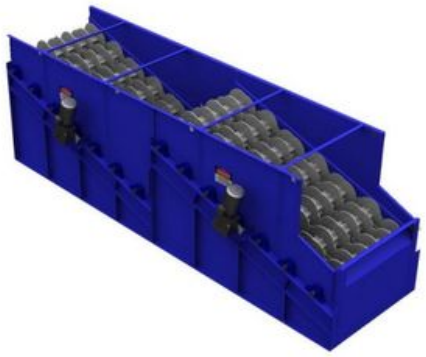


Figure 6-9: Disc screen example.

Vibrating/shaker Screens[9]

- Similar to trommels and disc/star screens, vibrating screens have the waste going through different sized holes, effectively segregating waste by size.

Figure 6-10: Vibrating screen example.

6.3.2.3 Air Separation

Air Density Separator[10]

[9] Image used for illustrative purposes only. Taken from SPR Group's online page.

- An air density separator applies an air stream to separate materials based on size, shape, and density. Larger, heavier materials such as glass fall down, while lighter materials such as paper and plastic bags go through a separate compartment.

Figure 6-11: Air density separator example.

Zigzag Air Separator[11]

- A zigzag air separator separates lighter materials from heavier ones through an inflow of air from the bottom to the top, which swipes away lighter particles while heaver particles fall toward the bottom.

Figure 6-12: Zigzag air separator example.

6.3.2.4 Ballistic Separation

Ballistic Separators[12]

[10] Image used for illustrative purposes only. Taken from BMH Technology's online page.
[11] Image used for illustrative purposes only. Taken from Impact Group's online page.
[12] Image used for illustrative purposes only. Taken from BRT Hartner's online page.

- In ballistic separators, the waste is fed into an inclined plate which oscillates to set the material in motion. Heavy and spherical or cubic parts roll down, while flat and light components move upwards. The sieve creates an additional third fraction;
- Ballistic separation usually takes place after the waste has been sorted by size and density.

Figure 6-13: Ballistic separator example.

6.3.2.5 Magnetic Separation

Magnetic Separators[13]

- Magnetic separators remove ferrous metals from the waste stream through a magnetic system. It can either lift the metals or hold them to the conveyor as exemplified in Figure *6-14*.

Figure 6-14: Magnetic separator example.

Eddy Current Separation [14]

[13] Image used for illustrative purposes only. Taken from ERGA's online page.
[14] Image used for illustrative purposes only. Taken from Bunting's online page.

- Eddy current separators apply an electrical current to non-magnetic metal such as aluminum, thus granting them magnetic properties and making them able to be removed through magnetic attraction.

Figure 6-15: Eddy current separator example.

6.3.2.6 Sensor Technology

Optical Sorters[15]

- Optical sorters identify and sort materials through Near Infrared (NIR) light reflected from their surfaces.

Figure 6-16: NIR optical sorter example.

X-Ray Transmission[16]

[15] Image used for illustrative purposes only. Taken from Steinert's online page.
[16] Image used for illustrative purposes only. Taken from Tomra's online page.

- X-ray transmission sorters can separate waste based on their atomic density.

Figure 6-17: X-Ray transmission example.

6.3.2.7 Mechanical Processing

Baler[17]

- A baler will compact the sorted waste in order to save space and make its maneuverability easier;
- Typically, more than one baler will be used for different materials.

Figure 6-18: Baler example.

Compactor[18]

[17] Image used for illustrative purposes only. Taken from Balemaster's online page.
[18] Image used for illustrative purposes only. Taken from Bulkmatech Cape's online page.

- A compactor will reduce the volume of the residual waste, saving storage space and facilitating transport.

Figure 6-19: Waste compactor example.

Waste Shredder[19]

- A waste shredder will reduce residual waste and bulky waste's volume in order to facilitate its storage on site prior to its removal.

Figure 6-20: Waste shredder example.

In addition to the above, other less common equipment may also be used, depending on the waste to process along with the quality output requirements. One such example is the bottle perforator, which is an equipment used to perforate bottles that have their lids on, and that otherwise would make it more difficult to compress into bales.

6.3.3 Storage Area for Recyclables

In general, stored bales should be stored in a way that helps retain their quality before sale. This usually means that the recyclable waste sorted throughout the different components of the waste processing area should be stored in a covered building, on an impermeable surface with containment to prevent spills and leaks to the soil, air, or surface water. Storage areas should not allow for the rain to pass through, as it not only leads to the production of leachates, but it will also degrade some components, particularly paper and cardboard. Additionally, storage areas for plastic waste should also limit the exposure to sunlight as UV rays degrade the physical and chemical structure of most plastics. Storing bales on pallets can also prevent their contamination and is therefore a viable option.

[19] Image used for illustrative purposes only. Taken from Wiscon Envirotech's online page.

The storage capacity for recyclables should be adequate considering the facility's expected processing requirements. Having adequate space allocated to store processed waste will protect the product from degradation while awaiting shipment, whereas it will also prevent contaminations from having multiple streams crowded together. Additionally, low space will lead to more frequent cargo shipments, and potentially more expenses if sold prematurely at lower volumes. At a minimum, waste storage areas should have a capacity to store three days' worth of waste for contingency.

6.3.4 Storage Area for Residuals

Residual waste from a MRF will consist mostly of non-recyclable waste, otherwise called contaminants, and recyclable waste that was not able to be sorted during the processing stage. Similarly to recyclable waste, residual waste should be stored in a covered building, on an impermeable surface with containment to prevent spills and leaks to the soil, air or surface water. Given the waste's properties, special considerations to odour issues should be given such as enclosing the waste.

The storage capacity for residual waste should be adequate considering the facility's expected processing requirements. At a minimum, waste storage areas should have a capacity to store three days' worth of waste for contingency.

6.3.5 Loading Area

Loading areas are the locations within the facility where trucks will arrive to load the processed waste, typically as bales for recyclables, or compacted waste for residuals, to be sent for the clients or disposal sites. These areas should have enough space for truck's maneuvers taking into account the expected size and characteristics of the vehicles.

Forklift[20]

[20] Image used for illustrative purposes only. Taken from OE Attachments' online page.

- A forklift vehicle will be one of the main components of the loading area, which will load the processed bales into outgoing vehicles;
- Although included in this section, forklifts should cross several areas, as a unit supporting the movement of waste through the facility.

Figure 6-21: Forklift example.

Weighbridge

- Truck weighing equipment for outgoing loads.

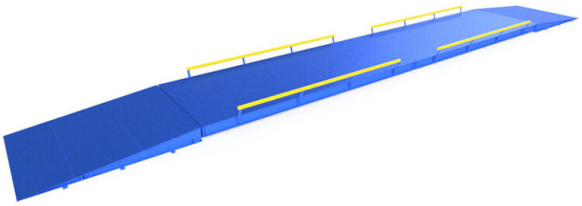


Figure 6-22: Weighbridge example.

6.4 Techniques for the control and prevention of emissions

Nuisance and pollution from the operational activities at a MRF have the potential to be an issue and a health hazard not only to the workers, but also to the neighbours and visitors of the facility. It's of extreme importance that at study and design stages, all due procedures are performed to assess the expected risks concerning the facility's operations and sensitive receptors in the vicinity. This assessment, along with the operational procedures and working plan should consider the best available techniques (BAT) to minimize and control all potential nuisance and pollution to arise from the facility, ensuring lower emissions and a reduction on the overall environmental impacts. High design and construction standards for instance can minimize several issues, but each nuisance must be addressed specifically as detailed below.

Essentially, these impacts fall into the following main categories:

- Emissions to soil and water;
- Emissions to air: dust, fine particulates and bioaerosols;
- Odour;
- Noise and vibration; and
- Pests.

6.4.1 Techniques for the Reduction of Emissions to Soil and Water

Although water spills and runoffs are not expected at the facility, litter will be a very common issue throughout the different areas. Provisions must be arranged to ensure that neither water discharges nor litter escapes the facility's premises. The following are some techniques to prevent water spills and other fugitive emissions into soil and groundwater:

- Impermeable surface and secondary containment;
- Adequate drainage infrastructure;
- Design and maintenance provisions to allow detection and repair of leaks;
- Buffer storage for contaminated surges.

Some specific techniques include the following:

- Having in place containment measures to prevent wastes from escaping. All bunds, humps, vessels, tanks, pipes, containers are sound, and maintained and checked as required;
- Providing and then maintaining the surfaces of operational areas, including applying measures to prevent or quickly clear away leaks and spillages, and ensuring maintenance of drainage systems and other subsurface structures;
- Ensuring that the drainage infrastructure is capable of collecting and discharging all runoff water in case of heavy rains;
- Having in place a regular inspection and maintenance programme of underground equipment;
- Inspecting pavements, drainage, and bunds daily. Particular attention is paid to signs of damage, deterioration, and leakage. Records are kept detailing any action taken. Damages and deterioration are repaired as soon as practicable. If the containment capacity or the capability of the bund, sump or pavement is compromised the waste is immediately removed until the repair is completed.

6.4.2 Techniques for the Reduction of Emissions to Air

The risk assessment performed through the several stages of establishment and operation of a MRF should identify any sensitive receptors of air emissions along with high-risk areas that are more likely to generate dust and other fine particulates, e.g., site roads and some waste types. The following measures should be considered in order to minimize air pollution exposure:

- Vacuum cleaning instead of sweeping, when feasible;
- A centralized ventilation and dust extraction system should be used to circulate the air and remove dust and particulates from working areas, and areas more susceptible of affecting sensitive receptors;
- Paving truck and vehicle areas, or water spraying non-paved access roads, if any, to control dust emissions;
- Implement speed limits on site roads;
- Perform dust monitoring on and off-site, if applicable;
- Keep MRF doors closed whenever possible;
- Use fast automatic opening/closing doors to minimize exposure;

- Align building openings to minimize exposure to prevailing winds.

6.4.3 Techniques for the Reduction of Odours

Unlike dirty MRFs, clean MRFs do not usually generate noteworthy foul odours, as they only process dry recyclable waste which is not expected to have a significant organic component. However, unclean recipients and contamination with organics due to poor segregation can all still lead to the generation of odours that will need to be considered. Design measures must be put in place to minimise nuisance arising from the generation of odours, which should include the following:

- Residual waste, particularly if containing high concentrations of biodegradable components, should be removed from the facility as soon as feasibly possible;
- A description or copy of any conditions or limits put in place by the Competent Agency, which relate to the prevention or minimisation of odour;
- Use odour neutralizing sprays and additives whenever odours can't be prevented;
- Use of central ventilation and air extraction systems adapted to deal with odours;
- Identification of the actions to be taken in the event of abnormal events or conditions which might lead to odour;
- Regular monitoring to be undertaken;
- An understanding of the impact in the event of abnormal events or conditions;
- Communication with local residents if an odour problem arises or is likely to arise.

6.4.4 Techniques for the reduction of Noise and Vibration

Several aspects can influence the generation of noise and vibration from a MRF, including, for example, the type of equipment being used to process the waste throughout its different stages. A noise and vibration management plan should be elaborated in order to minimize these issues, which should include the following:

- Describe the main sources of noise and vibration (including infrequent sources), and the nearest noise-sensitive locations. This description covers the following information for each main source of noise and vibration within the installation:
    - the source and its location on a scaled plan of the site;
    - whether the noise or vibration is continuous/intermittent, fixed, or mobile;
    - the hours of operation;
    - a description of the noise or vibration, e.g., clatter, whine, hiss, screech, hum, bangs, clicks, thumps, or has tonal elements;
    - its contribution to the overall site noise emission, e.g., categorised as high, medium, or low unless supporting data are available.
- Also provides the above information for the operation of infrequent sources of noise and vibration (such as infrequently operated/seasonal operations, cleaning/maintenance activities, on-site deliveries/collections/transport or out-of-hours activities, emergency generators or pumps and alarm testing);

- Details the appropriate noise surveys, measurements, investigations (which can involve detailed assessments of sound power levels for individual plant items) or modelling that may be necessary for either new or existing installations taking into consideration the potential for noise problems;
- Describes a protocol for response to identified noise and vibration incidents, e.g., complaints;
- Contains appropriate actions to be undertaken and timelines.

Techniques to reduce noise and vibration emissions include:

- Appropriate location of equipment and buildings: noise levels can be reduced by increasing the distance between the emitter and the receiver, by using buildings as noise screens and by relocating buildings' exits or entrances;
- Inspection and maintenance of equipment;
- Use of low-noise equipment (e.g., compressor with a noise level < 85 dB(A), speed-controlled pumps and fans, direct drive motors);
- Soundproofing of buildings to shelter any noisy operations including:
  - sound-absorbing walls and ceilings;
  - sound-isolating doors;
  - double-glazed windows.
- Use of vibration or acoustic insulation, or vibration isolation;
- Enclosure of noisy equipment;
- Reduction of noise propagation by inserting appropriate obstacles such as protection walls, embankments, and buildings.

6.4.5 Techniques for the Control of Pests

Similar to odour Organic waste can attract a variety of pests, including flies, vermin, rats, birds, among others, which can lead to health issues to staff and sensitive receptors in the vicinity. Some common protective measures related to the issue are:

- Hiring specialized pest control professionals;
- Seal or screen openings that may allow rodents and other pests to enter the facilities, such as door and window frames, vents, among others;
- Implement practices that prevent vermin appearance (e.g., odour control measures).

6.5 Future Technologies

Staying up to date with the latest technologies for waste identification, sorting and treatment is a vital part of establishing and operating a MRF, not only to achieve maximum efficiency and therefore profitability, but also to reduce any associated environmental impacts and potential pollution. Through sufficient technological developments, MRF can theoretically receive a mixed stream of waste and fully sort all its components into items that can be reused, recycled, or recovered, in line with the waste hierarchy, with minimum residual waste, and consequently lower environmental impacts.

At planning stage, in addition to common industry practices and equipment, studies should be conducted in order to assess both established and emerging solutions to improve the facility's operations, while at operational stages recurring market studies should be conducted to assess any changes to MRF's equipment and practices. Additionally, MRFs should be designed for flexibility, to allow for changes and updates to its processes at any time.

7 Operation and Maintenance Considerations

7.1 Waste Acceptance

Controlling the waste input at a MRF is one of the most important steps that will affect the entirety of the operations at a facility, directly impacting the pollution and nuisance potential, health and safety issues, material output quality, and the overall feasibility of the MRF. It's essential that any input control measure introduced is aligned with the waste acceptance requirements, both regarding the facility design and the corresponding license. At a minimum, upon reception the following procedures should be conducted:

- The waste should be weighed;
- The waste description should be matched with the actual content through a visual assessment at the inspection or tipping area. This visual assessment can be performed both before and after the waste is unloaded;
- Should a visual inspection not enable the facility operator to make a conclusive verification regarding the contamination of the load, further testing can be required;
- A record should be made for every batch including waste type, quantity, source, and transporter.

Acceptable materials, along with contaminants and prohibitive items should be clearly stated with any contracting party in order to ensure good input feed. Typically, when compared to private companies and institutions, entities processing municipal solid waste from residential areas have lesser control regarding the materials deposited into the bins and therefore more difficulty in assuring compliance, however, with no input control MRFs can have significant operational constraints and even become unfeasible. To address this issue, some measures as described in Section 4.1 can be adopted to improve waste input quality such as education and sensibilization.

Commonly, loads containing contaminants can result in extra fees for the generator, while loads containing significant amount of contaminants and prohibitive items will be rejected on arrival, leading to issues for all parties involved. In order to avoid such issues, non-acceptable items should be established at contracting level, along with acceptable contamination levels. A non-exhaustive list of typical contaminants is described in Table *7-1*.

Table 7-1:Typically accepted materials and contaminants per stream at a MRF.

Material	Acceptable	Contaminant
Plastic	Jars; jugs; tubs; bottles; cups; cartons	Plastics that are not containers (e.g, hangers, toys, etc); plastic container of hazardous item; styrofoam containers; compostable containers; etc
Metal	Aluminum beverage cans/bottles; food cans; aluminum foil; aerosol cans	Metal items that aren't cans/lids or foil (e.g., wire hangers, pots, pans)
Glass	Drink bottles; food jars	Any glass that is not bottle or jar
Paper / Cardboard	Books; cartons; corrugated cardboard; envelopes; magazines; newspapers; office paper; wrapping paper	Paper and cardboard contaminated with grease; sanitary paper; water resistant paper; wax coated or wire reinforced cardboard

Other contaminants common to every stream can be identified such as textiles, food waste, green waste, inert waste (sand for example), among others. Additionally, even some waste usually acceptable can be rejected if, for example, the waste is composed of hybrid items made up of near equal part of different materials or 3+ different materials, or, in the case of containers, if they are not empty.

Prohibitive items, on the other hand, are those that do not meet the acceptance criteria, and can not only lead to issues for the material output, but also cause major problems for the system and endanger the workers. For these items, any percentage detected within the load will lead to immediate rejection. The following is a non-exhaustive list of some common prohibitive items:

- Construction and demolition waste;
- Medical and biological waste;
- Explosives/flammables/combustibles;
- Bulky waste;
- Batteries; and
- Materials coated in liquids such as paint, petroleum, or chemical substances;
- Any waste classified as hazardous according to the provisions of the Implementing Regulations.

In addition to the above, some waste is difficult to process due to its nature, and the operational constraints arising from the inclusion of such waste into the feedstock can lead to increased processing time, malfunctions, and financial losses. One such item is, for example plastic bags. Being such a resistant and malleable material, plastic bags get frequently entangled in several machines, decreasing their functionality, and leading to malfunctions. As such, several facility operators decide to exclude this item from their scope, effectively treating it as a prohibitive item. Over the years, newer equipment has been designed to better deal with these complicated items, but their inclusion can still lead to issues in several cases, and their inclusion should be a decision performed by each operator based on the facility scope and equipment to employ.

7.2 Material Sorting

Material sorting at any MRF will consist of a sequence of several units that will process the waste through multiple stages, with different levels of mechanization (may include more or less manual labour), depending on the scale and financial investment of the facility, as detailed in Section 6.2. The equipment to use will be a combination of the different technologies mentioned in Section 6.3, adjusted to the facility needs. This means that the equipment layout order within the processing sequence can change significantly, even between MRFs processing the same type of waste from similar land uses.

Figure *7-1* displays a common waste processing sequence at a clean MRF, from waste generation to final product.

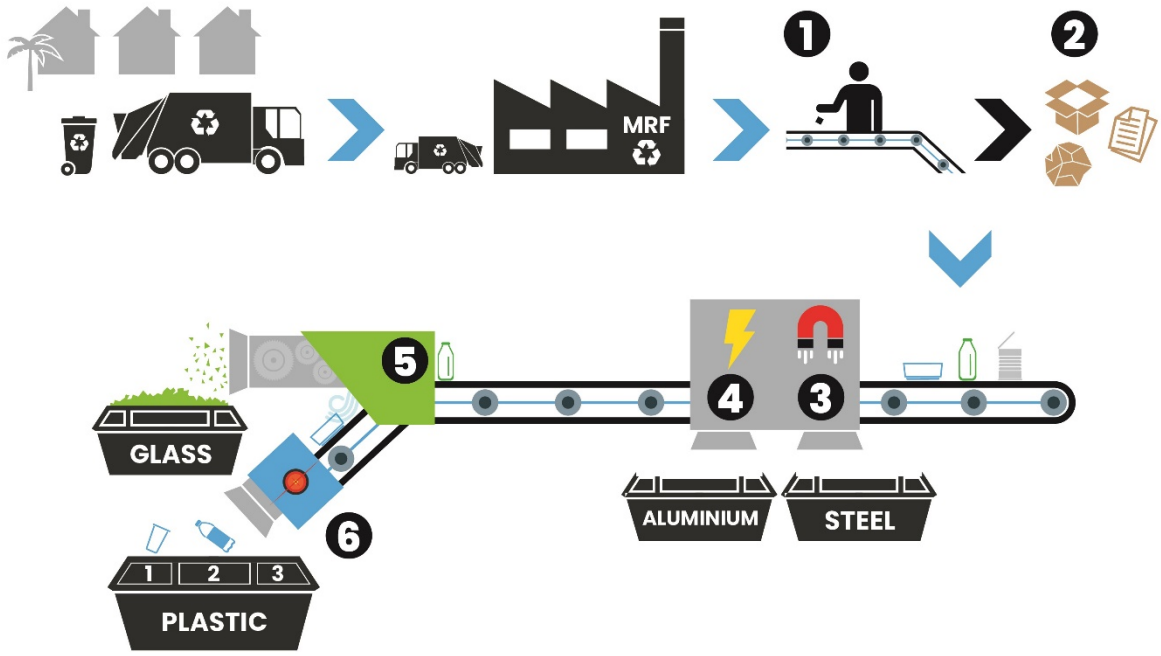


Figure 7-1: Waste processing sequence example at a clean MRF.

The abovementioned sequence can be described as follows:

1. **Pre-sorting –** At this stage, the waste will be processed in order to remove the bulky components along with some non-recyclable and residual waste. This is most commonly performed by manual sorters, although automated units already exist at MRFs capable of performing this task;
2. **Screening –** Screening is intended for the separation of waste into different sizes. It is usually at this stage that paper and cardboard is removed, since the longer it remains in the mixed input stream, the more likely it is to get contaminated and to lose quality;
3. **Ferrous Metal Separation –** At this stage, electromagnets are used for separating ferrous metals from the remainder of the waste;
4. **Non-ferrous Metal Separation –** This stage will segregate the remaining metallic components of the waste that are non-magnetic, and that have not yet been separated at other stages, such as aluminium, copper, lead, nickel, etc;
5. **Air Classification –** The remaining waste stream goes through an air stream with sufficient velocity to separate light and heavy materials. Particularly, this stage will focus on extracting lightweight plastics and glass from the remaining stream;
6. **Sensors –** The waste goes through sensors (can be Near Infrared (NIR), X-Ray, or others) which will sort the waste by visual/chemical characteristics such as colour and atomic density. The above example uses optic sensors to separate plastic into different resin types.

By the end of the sorting sequence, waste should be segregated into several different streams taking into account the output requirements and the MRF's design. Typically, the streams to be generated in a clean MRF include the following:

- Paper;
- Cardboard;
- Ferrous metal;
- Non-ferrous metal;
- Clear glass;
- Coloured glass;
- Plastic (split into different materials, i.e., PET, HDPE, LDPE, etc, as required/feasible); and
- Residual waste (which may include unsorted recyclables in addition to some non-recyclable waste).

7.3 Output Management

After materials are sorted, decisions must be made on whether they should be mechanically processed in order to have their size reduced through, for example, a shredder or a baler.

Shredders are more commonly applied to organic waste, since it increases the surface area and therefore air exposure, accelerates decomposition, reduces odours, and promotes dryness. As such, this equipment is commonly included in dirty MRFs, which are not within the scope of this Technical Guideline as it focuses on clean MRFs but can also be used to process larger items to reduce volume and facilitate storage, thus being a common component of clean MRFs as well.

Balers, on the other hand, are a very common piece of equipment that will compact the sorted waste, allowing it to be stored and transported with the highest cost efficiency through the maximization of storage space and volume in each load. Bale selection is critical part of MRF establishment as the resulting output must meet market requirements in terms of size, density, and weight. Additionally, careful consideration must be given to the selection of materials to be baled, as depending on the input material and process efficiencies, baling materials with significant levels of contamination can lead to large batches of sorted items being lost or having their market value dramatically reduced.

7.3.1 Quality Assessment

The set-up and implementation of an output quality management system, so as to ensure that the output of the waste sorting is in line with the expectations of contracted 3rd parties, is another relevant tool to implement.

This management system allows verification that the characteristics of the waste output are in line with the expectations, which may be product specifications, sorting efficiency rate, etc.

The management system also helps monitor and optimise the performance of the waste sorting and, for this purpose, it may include a material flow analysis of relevant components throughout the waste treatment.

The use of a material flow analysis is risk-based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety, and environmental impact as well as the knowledge of the previous waste holder(s).

7.4 Facility and Equipment Maintenance

Facility and equipment maintenance are a critical component of the daily operations at any MRF as it will allow to maintain performance levels and product quality. Equipment such as screens can easily become

plugged with plastic and other materials, reducing its ability to process waste, and resulting in lower quality screening, while optical sorters for example can have performance issues due to the accumulation of dirt in the optics. If not maintained properly, every equipment, in addition to the lower performance, can end up requiring downtime, which would mean at the very least loss of revenue and increased expenses, and also lead to environmental constraints such as leaks, spillages, among others.

Some considerations regarding the choice of equipment can help prevent wear and reduce maintenance requirements. For instance, choosing equipment with newer technologies or equipment better fit to handle the waste expected, can lead to streamlined performance.

The following are some considerations to follow related to facility and equipment maintenance at a material recovery facility:

- Perform frequent preventative maintenance of processing and control equipment (i.e., cleaning, greasing, etc);
- Conduct periodic testing of storage equipment to search for signs of decaying structural integrity;
- Regularly inspect the facility looking for cracks, worn equipment, leaks, etc;
- Floors and walls should be cleaned frequently; and
- Drain holes should be cleared of debris.

Best practice dictates that equipment maintenance should be performed outside of working hours to prevent equipment downtime, and also to prevent maintenance being conducted on working equipment which could represent serious health risks.

8 General Health and Safety Considerations at Licensed Material Recovery Facilities

8.1 Occupational Health

Health and Safety requirements can be defined as the regulations and procedures intended to prevent injury and ill health to employees and those affected by their work. Normal activities on a MRF expose the workers, neighbouring communities, and environmental receptors to significant risks, potentially affecting not only those directly involved but a significantly larger population.

The organisation or facility management must:

- Provide changing rooms and toilets for personal hygiene and somewhere safe to eat and drink;
- Provide personal protective equipment; such as overalls, safety boots, safety gloves, masks, goggles or safety glasses, and head covers, if required;
- Provide first aid kits and other medical emergency equipment as relevant, along with adequate training on how to use them; and
- Implement an occupational health and safety program for those handling waste, including:
    - maintain a special file for each employee including the dates of examinations and vaccinations they received and any findings or reactions (this file shall be kept in the workplace); and

- report work injuries and, unless otherwise specified by the KSA government, record these against each employee, each job function, location worked and overall, for the facility.

All structures must be located in a suitable area of the site to allow control of day activities whilst also taking account of health and safety aspects.

Additional recommended operational measures include:

- Doors and windows should be kept closed during operation; the cleanliness of the control cabin should be maintained;
- With cleansing and servicing work, which generate considerable amounts of microbial aerosols (e.g., bio-filter exchange), respiratory protection should always be worn; and
- The driveways and working areas should be moistened, kept dust-free and cleaned regularly preferably with a sweeper or industrial vacuum cleaner.

8.2 Safety Equipment

All licensed waste facilities should be equipped with the following:

- Suitable personal protective equipment (PPE) appropriate for the type(s)waste being handled, for all staff involved. Such PPE should include, as a minimum:
  - Eye protection, such as safety glasses, goggles, or a visor;
  - Gloves of suitable material to prevent penetration by sharp objects or by chemicals according to what is handled;
  - Safety boots;
  - Safety helmets if working under beams with high objects;
  - Suitable skin protection/covering;
  - Face masks to prevent inhalation of particulates in dusty atmospheres; and where working with plant or where vehicles are present;
  - High-visibility vests or similar.

- An internal communications or alarm system capable of providing immediate emergency instruction or warning to all personnel;
- A device, such as a telephone (immediately available at the scene of operations) or a hand-held, two-way radio, capable of summoning emergency assistance from local fire departments, ambulance, or emergency response teams;
- Where combustible and/or flammable wastes are stored, storage areas should be equipped with automatic smoke detection and, where necessary, fire suppression systems such as automatic sprinklers or other fire suppression systems;
- Portable fire extinguishers, fire control devices (including special extinguishing equipment, such as that using foam, inert gas, or dry chemicals), spill control materials and decontamination supplies; and
- Water at adequate volume and pressure to supply hoses, foam-producing equipment if appropriate.

All PPE and emergency equipment must be tested regularly and maintained to ensure proper operation.

Where combustible wastes or are stored or processes, it is good practice to develop a fire prevention and management plan, agreed with the relevant emergency services and approved by the Centre, which covers the management of combustible and/or flammable wastes, fire detection, suppression and fighting equipment and emergency procedures.

In addition to PPE and the emergency collective protection equipment mentioned above, other collective protective equipment should be used whenever possible to minimize the risks associated with certain areas or machinery in the MRF, with some examples as follows:

- Use ventilation and exhaust systems;
- Protection of circuits and electrical equipment;
- Use fixed guards to enclose dangerous machinery parts;
- Use of high visibility signs to alert for high injury risk operations;
- Use movable guards when access to dangerous parts is essential. These guards should be fitted with interlocking devices so that the machine cannot start before the guard is closed nor opened while the machine is still moving; and
- Use perimeter guarding/fencing to prevent accidental exposure.

8.3 Profession Training and Certification

Facilities will only be operated by qualified and trained personnel. Therefore, the MRFs' Service Provider will regularly offer adequate training and education to its staff to ensure they are well-equipped to manage the waste streams safely. Furthermore, the Service Provider will ensure to provide certificate proving the fitness and health of workers on an annual basis.[21]

In detail, candidates who wish to be certified must have knowledge and be trained in all of the following areas:

- Material Recovery Facility (MRF) theory, site infrastructure and basic design concepts including how features protect groundwater, surface water and air quality;
- MRF site operations such as:
  - Handling of waste including the movement, sorting, and storage of waste;
  - Receiving and transporting waste for onward transfer;
  - Site security.
- Regular maintenance of surface water control systems;
- Monitoring and reporting requirements specific to the relevant MRF including spills and storage requirements;
- Employee health and safety to include hazardous substances, PPE, and clean up requirements;
- Use of first aid kits and medical emergency equipment;

[21] (The Implementing Regulations of the Waste Management Law, 2021)

Employee training to include developing, implementing, and documenting training programmes for all personnel at the MRF. Prior to commencing work involving handling chemical substances or hazardous wastes, all personnel must be familiar with the relevant hazardous properties and instructed on what to do in case of emergency. Such instruction or training must include, as a minimum, the following:

- How to report a fire, injury, chemical spill, or other emergency;
- The location of emergency equipment, such as safety showers, eyewashes and first aid kits;
- The location of fire extinguishers and spill control equipment;
- The locations of all available exits for evacuation; and
- Names and phone numbers of the designated emergency coordinator and an alternate.

Training-related documents and records must be kept at the facility. These must include a job title for each person and the name of the employee filling that position. Also, a written job description is needed for each position and records documenting that the employee holding that position has completed the training or job experience satisfactorily. Finally, the files must contain the training records on current personnel and past employees for three years.

8.4 Accident Management Plan

An Accident Management Plan must be prepared for each facility at the time of license application. Once operational, the facility will have the plan in place (reviewed at least once every three years or as requested by the competent authority, or in an event of an accident) which identifies:

- The likelihood and consequence of accidents; and
- Actions to prevent accidents and mitigate any consequences.

A structured accident management plan includes the following:

- Identifying the hazards to human health and environment posed by the MRFs;
- Particular areas to consider may include waste types, overfilling of vessels, failure of equipment (e.g. over-pressure of vessels and pipework, blocked drains), failure of containment (e.g. bund and/or overfilling of drainage sumps), failure to contain firefighting water, making the wrong connections in drains or other systems, preventing incompatible substances coming into contact, unwanted reactions and/or runaway reactions, emission of an effluent before adequate checking of its composition has taken place, vandalism/arson, extreme weather conditions, e.g. flooding, very high winds;
- Assessing all risks (hazard multiplied by probability) of accidents and their possible consequences. Having identified the hazards, the process of assessing the risks can be viewed as addressing six basic questions:
    - What is the estimated probability of their occurrence? (Source, frequency);
    - What may be emitted and how much? (Risk evaluation of the event);
    - Where does it go? (Predictions for the emission – what are the pathways and receptors?);
    - What are the consequences? (Consequence assessment – the effects on the receptors);

- What is the overall risk? (Determination of the overall risk and its significance for the environment);
- What can be done to prevent or reduce the risk? (Risk management – measures to prevent accidents and/or reduce their environmental consequences).

In particular, identifying fire risks that may be posed for example by:

- Arson or vandalism;
- Self-combustion (e.g., Due to chemical oxidation);
- Plant or equipment failure & other electrical faults;
- Naked lights & discarded smoking materials;
- Hot works (e.g., Welding or cutting), industrial heaters and hot exhausts;
- Reactions between incompatible materials;
- Neighbouring site activities;
- Sparks from loading buckets;
- Hot loads deposited at the site.

The depth and type of assessment will depend on the characteristics of the plant and its location. The main factors taken into account are:

- The scale and nature of the accident hazard presented by the plant and the activities;
- The risks to areas of population and the environment (receptors);
- The nature of the plant and complexity of the activities and the relative difficulty;
- In deciding on and justifying the adequacy of the risk control techniques.

- Identifying the roles and responsibilities of personnel involved in accident management. Together with this, clear guidance is available on how each accident scenario needs to be managed; for example, containment or dispersion, to extinguish fires or to let them burn;
- Establishing communication routes with relevant authorities and emergency services both before and in the event of an accident. Post-accident procedures include an assessment of the harm that may have been caused and remediation actions to be taken;
- Putting in place emergency procedures, including safe shutdown procedures and evacuation procedures;
- Appointing one facility employee as an emergency coordinator to take leadership responsibility for implementing the plan. It is important that the facility offers training to its employees to perform their duties effectively and safely so that staff know how to respond to an emergency.

9 Data Recording, Monitoring, and Reporting

9.1 Data recording

It is the responsibility of the operator of a MRF to implement, use and maintain a computerised waste tracking system to hold up-to-date information about the available capacity of different parts of the facility and to make sure that the facility has enough waste storage and process capacity for the incoming acceptable waste.

The Service provider (MRF operator) shall record, monitor, and report data on waste according to the license requirements as issued by the Centre. The minimum information to be kept up to date are as follows:

- The details of all waste received at the site, including date and time, the source and nature of waste, including the original producer's details and any waste code(s), weight, details of the transporter, the vehicle, and the driver;
- Details of any non-conformances and rejections, including consignment notes for waste rejected because is hazardous;
- The details of the outputs obtained after the waste treatment in the plant including the weight and the final destination. In the case of residues/rejects redirected to another waste facilities the information recorded will include also details of the transporter, the vehicle, and the driver;
- The details on the duration of the outputs stored within the site awaiting recovery/recycling;
- Any incidents that did result, or could have resulted, in an uncontrolled or unpermitted release from the site, such as a spillage of waste into the surface water drainage system; and
- Any accidents involving waste or waste transporting vehicles or waste processed in the plant that result in injury to staff or the public or serious damage to property.

The waste recording system shall be able to generate information for the waste streams accepted for treatment in the waste facility, the following as a minimum:

- The total amount of waste present on site at any one time;
- A breakdown of the waste quantities stored pending on-site processing or awaiting onward transfer;
- Where a batch of waste is located based on a site plan;
- The quantity of waste on site compared with the limits set out in the license/permit;
- The length of time the waste has been on site compared with the limits in the license/permit.

Note: in addition to the above the service providers shall record, monitor, and report all environmental related parameters (water quality, air quality, noise, dust etc) according to the requirements of the Environmental Permit issued by the competent authority (NCEC) for the plant.

9.2 Periodic inspections and internal audits

Each facility should be monitored, either at random or at regular intervals to ensure that the site is being operated in accordance with:

- The working plan agreed with the Centre and incorporated into the licence; and
- Any conditions in the licence issued by the Centre.

This monitoring should be conducted by the designated responsible person, who should, *inter alia*:

- Periodically but irregularly undertake inspections to check the integrity of the equipment in the facility to prevent/reduce the risk of major accidents and to ensure that all primary and secondary containment is fit for purpose;
- The responsible person should ask questions of those responsible for handling the waste as to whether they have encountered any problems and what suggestions, if any, they may have for improvements; and
- the data on waste inputs and outputs should be interrogated and the amount and types of different wastes in store compared with the amount of waste visible in the temporary storage area and any differences noted and acted upon.

9.3 Waste Data Reporting

The designated person should use the data recorded above to monitor the production and/or the management of waste at the MRF on an ongoing basis. The designated person must prepare reports regarding all aspects related to waste such as production, processing, after treatment storage, waste redirected to 3rd parties for recycling/recovery or final elimination and provide a copy of these to the Centre periodically as determined by the Regulations.

All reporting must be carried according to the license requirements as issued by the Centre, which can be on a monthly or yearly basis, and the data to be reported can include the following as an example:

A. General data:
   - The facility name, address, and permit number;
   - Site location (e.g., address of the site where works are carried out);
   - Name and contact detailed of the person in charge with data recording and reporting.

B. Data on the waste processed in the Facility:
   - Amount of waste accepted in the facility by waste stream and fraction including any waste code;
   - The total quantity in tons of output (recycling materials, SRF/RDF) produced at the facility during the period covered by the report;
   - The total quantity in tons of output (recycling materials, SRF/RDF) removed for use or disposal from the facility during the period covered by the report;
   - The results of analytical testing of the marketable outputs, as well as all effluent to be disposed of or to undergo further treatment; and
   - Amount of waste/products awaiting transfer.

C. Data on Service Providers.

APPENDIX 1 - Data Reporting Template displays a table that can be used as template for recording and reporting waste data.

Failure to maintain records or provide documentation when solicited is a violation of the Law and will lead to legal consequences.

In addition, the Centre should analyse the data from each facility to compare the amounts of different categories of waste reported and seek reasons or explanations for any significant differences.

APPENDIX 1 - Data Reporting Template

A. General information

- Name of the Waste Facility;
- Site Location;
- Period covered by the report and Completion date;
- Name and contact details of the person who filled in the data and approved the figures.

B. Information on resources and waste

B.1 Waste processed

Crt	Waste received in the Plant				
	Waste generator	Waste Transporter	Waste Stream/Fraction	Waste code	Amount Tones
1					
2					

B.2 After treatment products

Crt	Waste/products	Total Amount, tone	Amount directed to 3rd parties, tone	Amount in stock, tone
1	Recycling materials			
	- Paper/cardboard			
	- Glass			
	- Plastic			
	- others			
2	RDF/SRF			
3	Rejects			

C. Information on 3rd parties

- Information on waste transporters

Details of the entities who has purchased the products including name and address, amount of waste/materials purchased (by stream and total).

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National Center for Waste Management