ZDHC Recycled Polyester Guidelines

Version 1.0

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Contents

NOTES

Any mention of innovations and/or innovative practices within this document are provided as examples and shouldn't be construed as the only ones available. Organisations are responsible to conduct their own research into all possible solutions to determine the best one for them.

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List of Terms (Abbreviations)

AP	Alkylphenol
APEOs	Alkylphenol ethoxylates
BPA	Bisphenol A
BOD	Biological Oxygen Demand
BHET	Bis(2-hydroxyethyl) terephthalate
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical oxygen demand
CH_4	Methane
DO	Dissolved oxygen
DMT	Dimethyl terephthalate
EG	Ethylene glycol
MEG	Monoethylene glycol
PAH	Polycyclic Aromatic Hydrocarbons
PFCs	Perfluorinated and Polyfluorinated Chemicals
PFAS	Perfluorinated and Polyfluorinated Chemicals
PET	Polyester
PPE	Personal protective equipment
rPET	Recycled polyethylene terephthalate
TPA	Terephthalic acid
VOCs	Volatile Organic Compounds

Definitions

Term	Definition
Pre-consumer material*	Material diverted from the waste stream during the manufacturing process. Excluded is the reutilisation of materials such as rework, regrind, or scrap generated in a process and capable of being reclaimed within the same process that generated it.
Post-consumer material*	Material generated by households or by commercial, industrial and institutional facilities in their role as end users of the product that can no longer be used for its intended purpose. This includes returns of materials from the distribution chain.
Reclaimed material*	Material that would have otherwise been disposed of as waste or used for energy recovery has instead been collected and reclaimed as a material input, in lieu of new primary material, for a recycling process. It may also be referred to as recovered material.
Transesterification	In organic chemistry, transesterification is the process of exchanging the alkoxy group of an ester compound by another alcohol.
Bottle-to-Textile recycling	A process of converting used plastic bottles, typically made from polyethylene terephthalate (PET), into fibres used to manufacture textiles.
Textile-to-Textile Recycling	A process of recycling pre- and post-consumer textiles into new textile products.

* *Source: Terms and Definitions for Textile Exchange Standards and Related Documents, V1.4*[1]

Collaborative Process and Acknowledgements

The fundamental principle of collaboration at ZDHC was followed in developing this document. A recycled polyester focus group was formed and a technical consultant was also engaged in the project, completing a team of experts to provide inputs on recycling processes, chemical usage and environmental impacts. The ZDHC Fibres and Materials Competence Centre and Roadmap to Zero (RtZ) Delivery teams co-ordinated this focus group through calls, e-mails and 1:1 calls to gather and collate inputs on the topics. Inputs were also collated from external stakeholders such as Revalyu Recycling (India) Limited, Zhejiang Jiaren New Materials Co.Ltd., Sulochana Cotton Spinning Mills P Ltd and Textile Exchange.

Based on the discussions and inputs gathered, a draft document was prepared by ZDHC and reviewed by the focus group members. The suggestions and comments received from them were incorporated into the draft to develop the guidelines. We acknowledge and thank the contribution of the focus group members, consultants and external experts for their assistance in the development of this document. Please see the end of this document for a full list of acknowledgements.

Introduction

Background

In the realm of sustainability, polyester recycling stands as a beacon of innovation and environmental responsibility. Brands increasingly market their clothing as 'recycled polyester' and 'sustainable', often sourcing these materials from polyester (PET) bottle recycling facilities (bottle-to-textile recycling). This shift has marked a positive trend towards reusing plastic waste, significantly reducing dependence on virgin raw materials used in the manufacture of polyester fibres and also avoiding PET waste ending in landfills and water bodies. In the fashion industry, PET recycling is still predominantly using PET bottle waste as input and the share of textile-to-textile recycled material (that is, recycling of pre- and post-consumer textile waste into polyester fibres) is around 2% of all recycled polyester.[2]

The textile waste stream is a complex blend of various materials, including cotton, wool, viscose and synthetic fibres. Effective textile waste recycling demands meticulous sorting and selecting appropriate recycling processes tailored to each type of textile waste.

Chemical recycling is a promising option for textile-to-textile recycling. In this process, fibres are depolymerised and converted into their molecular components, enabling the production of high-quality new fibres. This process achieves a closed-loop system, promoting circularity and minimising waste.

ZDHC has developed the Recycled Polyester Guidelines to provide a framework for sustainable chemical management in recycled polyester production for bottle-to-textile and textile-to-textile recycling processes.

Objective

ZDHC Recycled Polyester Guidelines V1.0 sets mandatory and voluntary requirements for recycled polyester manufacturers regarding key chemicals used in polyester recycling processes, the recovery and reuse of these chemicals, safe chemical storage and handling, worker safety and the environmental impacts of commercially viable* processes on wastewater, air and sludge.

- **Mandatory requirements** are the elements that will be verified on the ZDHC platform.
- **Voluntary requirements** are the elements that we expect the manufacturer to have implemented for proper sustainable chemical management and to prepare its processes for future requirements.

The ZDHC Recycled Polyester Guidelines V1.0 covers:

1) **Input Management (Chapter 1)**

   This covers post-consumer PET bottles or pre- and post-consumer textile waste as feedstock and the chemicals used as inputs in the manufacturing of recycled polyester.

2) **Process Management (Chapter 2)**

   This covers:

   - cleaning and decolourising feedstock,
   - shredding the cleaned PET bottles or textile waste into flakes,
   - melting and re-extrusion into new fibres (for mechanical and thermo-mechanical recycling),
   - depolymerising polyester into its monomers using solvents, and repolymerising into new polyester fibres (chemical recycling),
   - decomposing cotton into cellulose powders and, enabling the separation of the polyester fibres from the polyester cotton blends (hydrothermal process).

* *Commercially viable means the process or technology is not at a laboratory or pilot scale but has been established as viable to make a profit through investments in a manufacturing plant that produces output available in the market for commercial sale on a regular basis.*

3) **Output Management (Chapter 3)**

This covers emissions of wastewater, sludge and air from the production of recycled polyester fibre.

Note: The details of the recycling techniques are provided in Appendix A

Scope

Feedstock

- Pre-consumer textile waste
- Post-consumer textile waste
- Post-consumer PET bottles
- Ocean-bound plastic waste

Processes

- Feedstock cleaning
- Decolourisation
- Recycling techniques:
    - Mechanical and thermomechanical recycling
    - Hydrothermal process
    - Chemical recycling
        - Glycolysis
        - Glycolysis followed by transesterification
        - Methanolysis
        - Hydrolysis (acid, alkaline and neutral hydrolysis)

Out of scope

- Thermolysis processes (gasification and pyrolysis)
- Biological recycling (enzymatic degradation, microbial degradation)
- Recycling processes not at a commercially viable scale

Connectivity

This document should be read in connection with the following ZDHC documents:

- **ZDHC Manufacturing Restricted Substances List (ZDHC MRSL) V3.1**
- **ZDHC Wastewater Guidelines V2.2**
- **ZDHC Wastewater and Sludge Laboratory Sampling and Analysis Plan (SAP) V2.1**
- **ZDHC Sludge Reference Document V1.0**

Summary of requirements in the Recycled Polyester Guidelines V1.0

Type of Recycling	Requirements
	Input Management
Mechanical, thermomechanical, hydrothermal and all chemical recycling	**Mandatory requirements (to be reported on the ZDHC platform)** ▪ Record input materials in a Material Inventory List (MIL). ▪ Record all purchased chemicals in the ZDHC Chemical Inventory List (CIL). ▪ Maintain Safety Data Sheets (SDS) and Technical Data Sheets (TDS) and record the information in the CIL. **Voluntary requirements (for guidance and preparation for future updates):** ▪ Assess input feedstock for hazardous substance risks. ▪ Familiarise with the ZDHC MRSL and encourage chemical suppliers to register their products on the ZDHC Gateway.
	Process Management
Mechanical, thermomechanical, hydrothermal and all chemical recycling	**Mandatory requirement (to be reported on the ZDHC platform)** **Solvent recovery (applicable only to chemical recycling facilities)** ▪ Glycolysis process: Ethylene glycol recovery ▪ Glycolysis followed by transesterification: Ethylene glycol and methanol recovery ▪ Methanolysis process: Methanol recovery **Voluntary requirements (for guidance and preparation for future updates):** ▪ Safe chemical storage ▪ Chemical handling and worker safety ▪ Training plan for chemical management
	Output Management
Mechanical, thermomechanical, hydrothermal and all chemical recycling	**Mandatory requirements (to be reported on the ZDHC platform)** **Wastewater and sludge** ▪ Test wastewater for conventional parameters and heavy metals twice a year (April and October cycles). ▪ Undertake a Root Cause Analysis (RCA) and a Corrective Action Plan (CAP) for any non-conformities detected. ▪ Report the major sludge disposal pathway used.
Mechanical, thermomechanical, hydrothermal recycling	**Mandatory requirements (to be reported on the ZDHC platform)** **Air emissions** ▪ Quantify, track and report GHG (Scope 1 and Scope 2) emissions.
Chemical recycling	**Mandatory requirements (to be reported on the ZDHC platform)** **Air emissions** ▪ Quantify, track and report GHG (Scope 1 and Scope 2) emissions. ▪ Quantify, track/test and report VOC (methanol, ethylene glycol, acetaldehyde and non-methane total hydrocarbons) emissions.

CHAPTER 1:

Input Management

Input management focuses on the responsible sourcing and handling of feedstock and the input chemicals used to manufacture recycled polyester.

This document focuses on two input management areas:

- Input feedstock management
  - Use of feedstock that is free from hazardous substances risks
  - Feedstock traceability
- Input chemicals management
  - Maintaining a Chemical Inventory List
  - Selection of safer and non-toxic chemicals to be used in manufacturing
  - Reducing the use of hazardous chemicals

1.1 Input feedstock management

The feedstock for polyester recycling processes includes:

- Pre-consumer textile waste
- Post-consumer textile waste
- Post-consumer PET bottles
- Ocean-bound plastic

These materials undergo mechanical or chemical recycling to be converted into new polyester materials suitable for textile manufacturing. Feedstock may contain unknown legacy chemicals from previous use. These could be harmful to human health and the environment, posing potential risks during the recycling process and through the recycled product. Therefore, understanding the source of feedstock and its chemical risks is essential for ensuring safety, maintaining quality, complying with regulations, optimising operations and enhancing traceability.

Mandatory requirements for input feedstock sourcing

a) Record input materials in a Material Inventory List to ensure feedstock traceability.

[Material Inventory List (MIL)](#)

Material Inventory List (MIL)

MIL Month and Year	
Facility Name	
Person inputing details	
Designation	
Email address	
Date completed	

No.	Material Category	Material form	Material Composition	Name of material vendor	Origin of the material/Feedstock	Quantity of purchased material (Kg)	Quantity of recycled material produce Kg)	Quantity of waste generated during operations (Kg)
	Choose from drop down menu	*Choose from drop down menu*	*Write compostion of material*	*Write the organisation name of the material vendor*	*Address of material vendor name*	*Write quantity of input material*	*Write quantity of product*	*Write quantity of waste*
1	Pre-consumer textile wa...	Yarn	90% PET, 10 % cotton	XXX	ZZZ Street, Apartment YYY City: VVV Town Postal Code: XYZ123 Country: Europe	5000kg	4970kg	30 kg
2	Post consumer PET Bot...	Washed Fl...	100% PET	YYY		80000 kg	79000 kg	1000 kg

Figure 1: Example of Material Inventory List (MIL)

b) Both mechanical and chemical recycling facilities should add below details to the MIL:

- Material category (PET bottle, ocean-bound plastic, pre- or post-consumer textile waste)
- Form of material
- Material composition
- Name of material vendor
- Origin of the material/feedstock
- Quantity of purchased materials
- Quantity of recycled material produced
- Quantity of waste generated during operations

Voluntary requirement for input feedstock

c) Assess input feedstock for hazardous substance risks: It is suggested that the following indicative substances in the input feedstock could be monitored through a random testing regimen for specific risks.

Figure 2: Hazardous substances risk in the input feedstock

Note: The hazardous substance risks outlined above apply exclusively to PET and PET-rich waste. They should not be referenced for other types of reclaimed materials.

1.2 Input chemicals management

Chemicals are critical in transforming post-consumer PET bottles and textile waste into new polyester fibres in polyester recycling. Besides cleaning agents used to clean feedstock from impurities, the following chemicals are used in polyester recycling processes:

Table 1: Chemicals Used in Polyester Recycling Processes

Chemical Category		Example	Use
Solvents		Ethylene Glycol (CAS No. 107-21-1) Methanol (CAS No. 67-56-1)	Solvent in glycolysis Solvent in methanolysis
Commodity chemicals	Metal catalyst	Antimony trioxide Antimony triacetate Antimony triglycolate Zinc acetate	Accelerates the polymerisation and depolymerisation
	Delustrants	Titanium oxide (TiO_2) Zinc stearate Calcium carbonate	To impart a matte finish in recycled polyester fibres
	Acids	Inorganic acids: sulphuric acid, nitric acid, hydrochloric acid etc. Organic acids: acetic acid, formic acid, etc.	Acid hydrolysis
	Bases	Sodium hydroxide, potassium hydroxide, sodium carbonate, sodium bicarbonate, ammonium hydroxide, etc.	Alkaline hydrolysis
	Oxidisers	Hydrogen peroxides potassium permanganate sodium hypochlorite	Decolourisation
Colourants		Dyes and pigments used in coloured masterbatches	Impart specific colours to recycled polyester.
Formulations	Cleaning/ washing agents	Wetting agents, antifoaming agent, detergents, dispersing agents, emulsifying agents, chelating agents	Removes dirt, oils and other contaminants from feedstock.
	Process aids, additives and finishing agents	Spin finish, coning oil, antistatic agents, stabilisers, plasticisers, UV absorbers, silicones, a functional additive used in masterbatches	Enhance the properties of the final product, e.g. spinnability, durability, flexibility, or functional properties.

Mandatory requirements for input chemicals

All chemicals used in the recycling processes should be recorded in a **ZDHC Chemical Inventory List (CIL)**. *(Please note that not all columns in the CIL template are applicable to recycled polyester manufacture at this stage).*

a) **Information that is required at a minimum and updated on a monthly basis:**

- Names of chemical products and chemical manufacturers
- Quantity delivered or in stock
- Consumption or usage
- Use/function of the chemical
- Lot/batch numbers
- Storage location
- Expiry date (if available)
- Date and version of Safety Data Sheet (SDS)

b) **Safety Data Sheets (SDS) and Technical Data Sheets (TDS)**

- Information on hazardous ingredients (CAS numbers and % composition)
- Hazard information (H-Statement(s)), given in Section 2 of the SDS
- Precautions required for identified hazards (P-Statements for storage and handling)

Voluntary requirements for input chemicals

c) **ZDHC MRSL Conformance**

- Suppliers are encouraged to familiarise themselves with the **ZDHC MRSL V3.1** and the potential risks in their input chemicals to prepare themselves for future updates for ZDHC MRSL conformance. It is to be noted that ethylene glycol and methanol, which are used in polyester recycling processes, are not included in the main list of the ZDHC MRSL V3.1 and are, therefore, out of scope.

- Suppliers should encourage their chemical suppliers to register their products on the ZDHC Gateway, at a minimum, for ZDHC MRSL Level 1 conformance through ZDHC Approved Certifiers.
- Suppliers can check and confirm the ZDHC MRSL Conformance of their input chemicals by registering on the ZDHC Gateway and accessing the ZDHC Gateway database for ZDHC MRSL conformant formulations. As a best practice, the data can be recorded in the Chemical Inventory List (CIL).

CHAPTER 2:

Process Management

This section sets mandatory and voluntary requirements for polyester recycling facilities to ensure that chemicals used in manufacturing are managed responsibly by recycling solvents and safe storage and handling for worker safety. Mandatory requirements are to be reported on the ZDHC platform by recycling facilities. This section includes:

- Solvent recovery in chemical recycling processes (mandatory requirement)
- Safe chemical storage (voluntary requirement)
- Chemical handling and worker safety (voluntary requirement)
- Training plan for chemical management (voluntary requirement)

2.1 Solvent recovery in chemical recycling processes

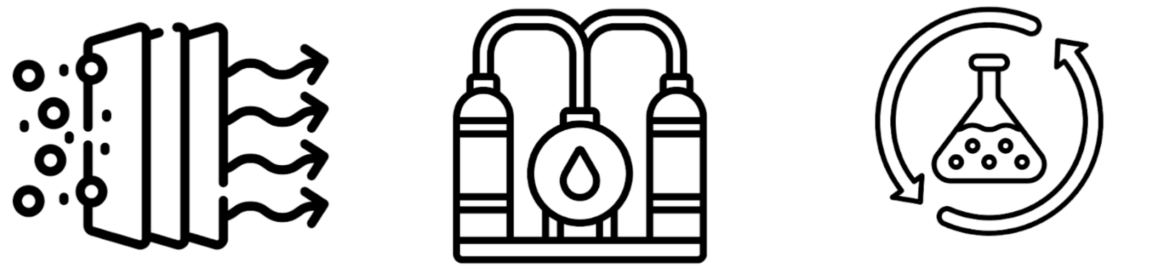
(mandatory requirement)

Solvent recovery should be implemented and reported on the ZDHC platform under process management by chemical recycling facilities using glycolysis and methanolysis techniques. For this, chemical recycling facilities should:

- Maintain records of solvent recovery activities and calculations as detailed in Sections 2.1.1 to 2.1.4 of this chapter.
- Meet the chemical recovery requirement, as mentioned in Tables 2, 3 and 4, based on the type of process (glycolysis, methanolysis etc.).
- Report chemical recovery data as a yearly average for the calendar year (1st January to 31st December) on a ZDHC platform to evaluate against the limit values.

2.1.1 Solvent recovery in glycolysis process

The solvent (ethylene glycol) recovery activities from the glycolysis reaction mixture that contains the desired monomers bis(2-hydroxyethyl) terephthalate (BHET), residual solvents and by-products are as per the following figure.[3-6]



1. Filtration: Solid impurities and unreacted polyester are removed from the mixture through filtration. This step ensures that only the liquid phase, containing the monomers and solvents, proceeds to the next stage.

2. Distillation: The liquid mixture undergoes distillation to separate the monomers from the solvents. During this process, the mixture is heated to different boiling points to evaporate and condense the solvents separately from the monomers.

3. Recovery: The distilled solvents are collected and can be reused in the glycolysis process. This recovery and reuse of solvents minimise waste and reduce the need for fresh solvent input.

Figure 3: Solvent recovery in the glycolysis process

Table 2: Ethylene Glycol Recovery Rates for the Glycolysis Process

Solvent Recovery	Minimum Requirement for Solvent Recovery
Ethylene glycol	90 %

2.1.2 Solvent recovery in glycolysis followed by the transesterification process

In the glycolysis followed by the transesterification process, polyester is first converted into BHET through glycolysis. BHET is then further converted into DMT via transesterification. Both stages, glycolysis and transesterification, are crucial for breaking down and repurposing polyester materials allowing for the recovery and reuse of the chemical components. To ensure the process is environmentally responsible the recovery of ethylene glycol (from glycolysis) and methanol (from transesterification) should be closely monitored and reported in accordance with Table 3.

Table 3: Ethylene Glycol and Methanol Recovery Rates for the Glycolysis Followed by the Transesterification Process

Solvent Recovery	Minimum Requirement for Solvent Recovery
Ethylene glycol	90 %
Methanol	95 %

2.1.3 Solvent recovery in the methanolysis process

The solvent (methanol) in the methanolysis process facilitates the breakdown of polyester chains into their monomer components, primarily dimethyl terephthalate (DMT), ethylene glycol (EG), methanol and other by-products.

After the methanolysis reaction, the mixture contains DMT, EG, excess methanol, and by-products. This mixture undergoes separation to isolate each component as mentioned below. [3-6]

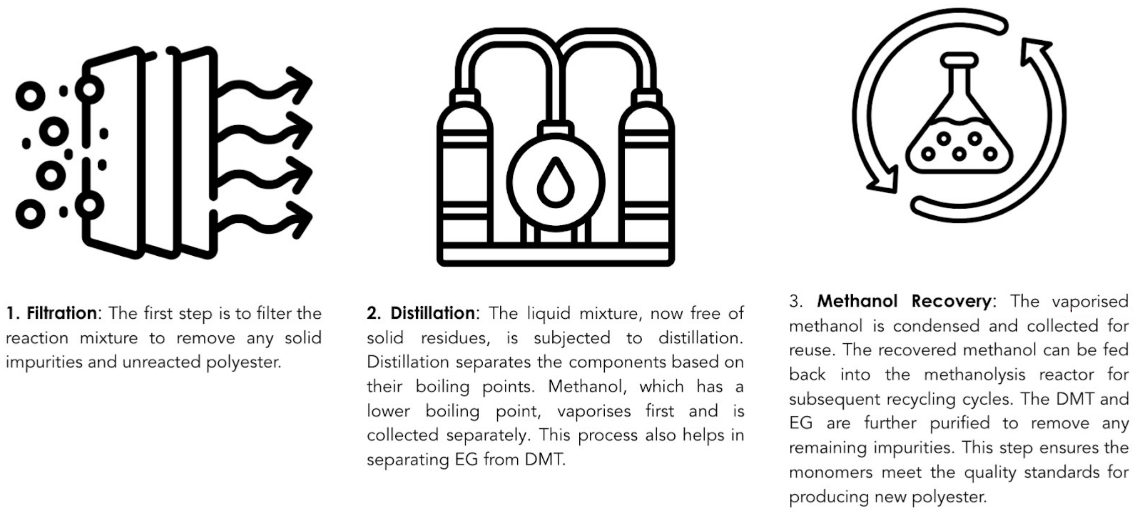


Figure 4: Solvent recovery in the methanolysis process

Table 4: Methanol Recovery Rates for the Methanolysis Process

Solvent Recovery	Minimum Requirement for Solvent Recovery
Methanol	95 %

2.1.4 Solvent recovery calculation

The solvent recovery efficiency formula calculates the percentage of solvent recovered during the recycling process.

$$\text{Solvent recovery efficiency (\%)} = \left(\frac{\text{Volume of solvent recovered}}{\text{Total volume of solvent used}} \right) \text{x100}$$

2.2. Safe chemical storage

(voluntary requirement)

These requirements include:

1) Designing a safe chemical store.
2) Labelling on chemical containers.
    - Ensure that all containers have labels communicating hazards.
    - implement actions to ensure chemicals are labelled correctly.
3) Prepare and display Chemical Safety Cards at storage points in the stores.

2.2.1 Designing a safe chemical store

Safe storage of chemicals is vital for ensuring worker safety and preventing accidents that can lead to fire or chemical incidents.

The facility should design the layout of the chemical store to ensure that chemicals are stored correctly and that the required emergency resources are available at the place of storage.

The figure below shows the design of a safe chemical store and the controls required that are described further as per the numbering in the diagram:

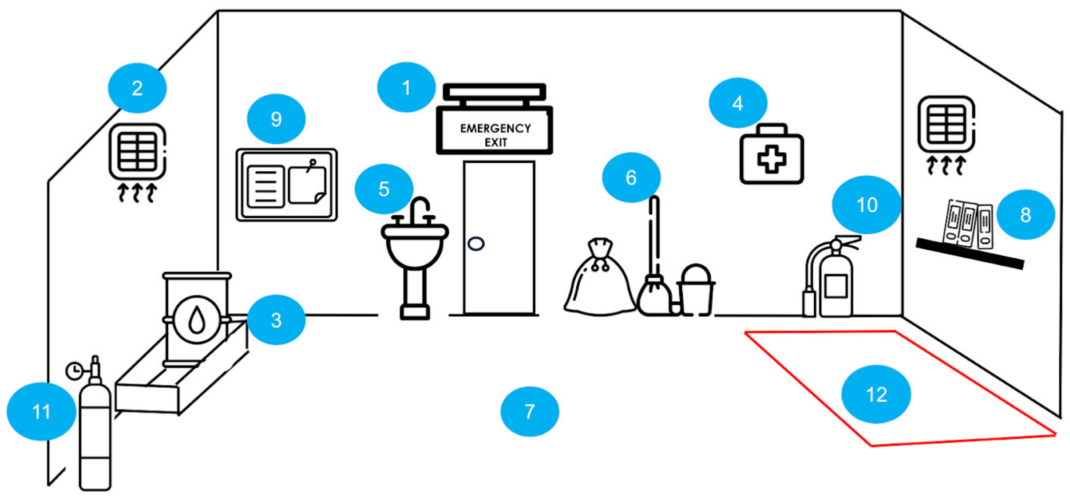


Figure 5: Design of a safe chemical store and the control requirements

1) The emergency exit is opposite the main entrance. There are no obstacles inside or outside it and the exit door opens outwards by push-bar handle.
2) There is cross-ventilation.
3) All liquid chemicals must have a secondary containment. Therefore, the chemical is contained in a confined space in case of spillage due to cracks or other reasons in the container.
4) First aid boxes are installed.
5) Eye and body wash stations are installed.
6) A spill kit is kept to contain any spillages.
7) The flooring should be impermeable to liquids and non-slippery. It should also be easy to clean and resistant to acids and organic solvents.
8) A physical file of all the chemicals' SDSs is kept in the stores in a place that is indexed and accessible to all staff.
9) Warning signboards are installed at key locations to keep staff informed of risks.
10) An adequate fire management system is installed, such as suitable fire extinguishers or fire alarm systems.

11) Gas cylinders, including LPG cylinders, are stored upright in a separate location, protected from direct sunlight and kept away from flammable, combustible, or oxidising chemicals.
12) A designated area is marked with a red (or the local required colour) border for non-conformant chemicals that are to be returned to the chemical supplier. Keep relevant documents in the vicinity.

2.2.1.1 Secondary containment

Some recommended methods for secondary containment are shown below.

Figure 6: Examples of secondary containment

The secondary containment must meet applicable local legal requirements based on chemical volume and container sizes. However, it is recommended that the volume of the secondary containment should be 110% of the primary container.

In the case of multiple containers stored together, the volume of the largest container should be considered, irrespective of whether the container is full or partially filled, and the secondary containment volume of 110% of this largest container should be provided.

As shown in the below figure, if two containers with volumes of 20L each and two containers with volume of 120L each are stored with one 300L volume container, then the secondary containment capacity for this storage cluster should be calculated as 330L (=110% of the largest volume container), irrespective of whether the 300L container is partially filled at the time of storage.

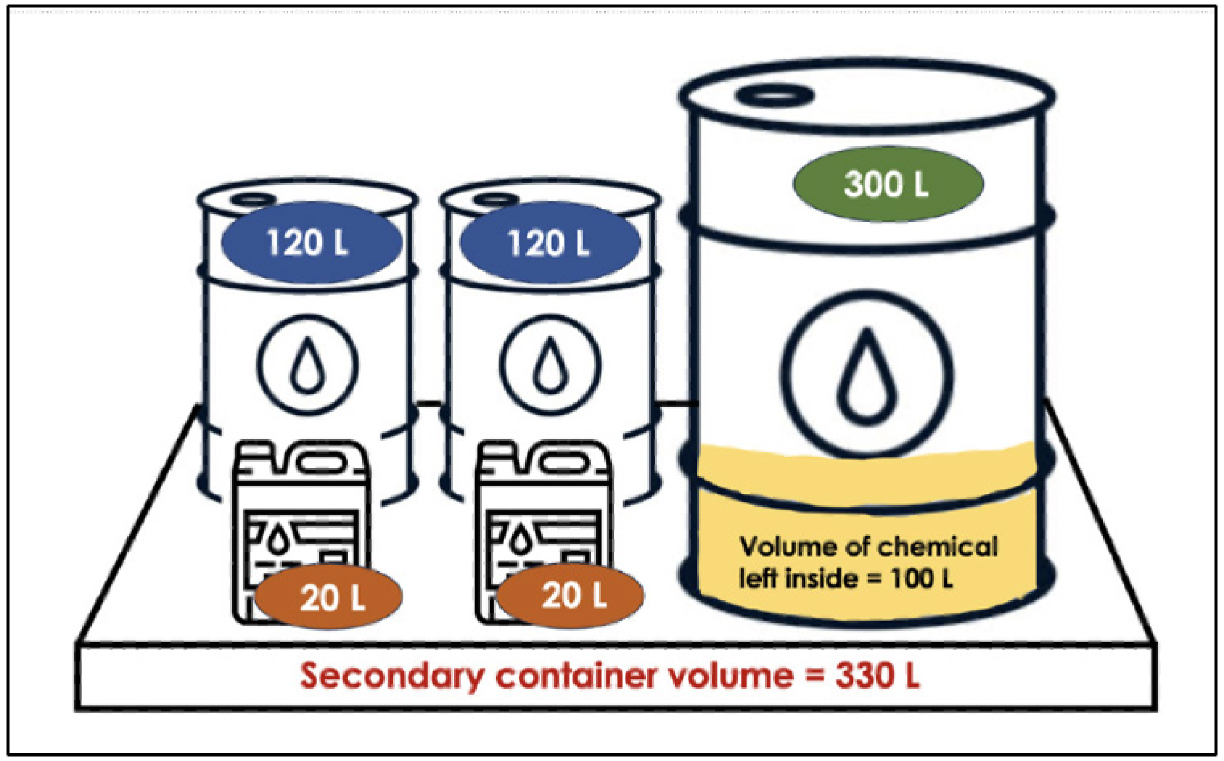


Figure 7: Secondary storage capacity calculation (Courtesy: Decathlon)

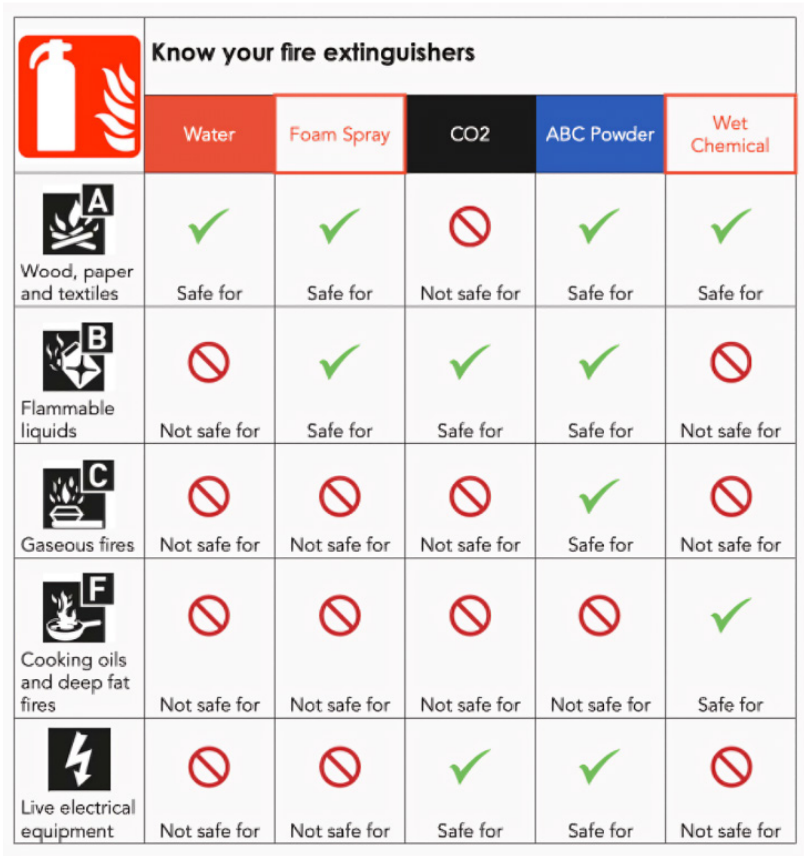
2.2.1.2 Fire management

The prevention of fire is the core principle of fire management. However, in the case of a fire outbreak, its spread can be prevented by managing one of three factors: suppressing the oxygen supply, fuel, or ignition source.

Typical fire safety measures (this list is not exhaustive)

- Fire alarm systems (sound and light) which are distinct from other alarms and notification systems.
- Fire extinguishers suitable for types of fire (class A, B, C or D) which are serviced regularly.
- Sand buckets, hydrants and fire hoses at chemical stores and other high-risk areas in the facility.
- Automatic sprinkler system at the place where flammable chemicals are stored.
- Emergency lighting along exit routes.
- Regular fire drills and training of staff on the use of fire equipment and evacuation methodology.
- Display “No Smoking” signs and prevent staff from smoking within the facility.

- Electrical wiring cables that are fire-proof and wiring systems that do not lead to short-circuit.
- Explosion-proof lighting should be installed in chemical stores.
- Segregated storage of chemicals identified as fire hazards with all fire safety systems.



Know your fire extinguishers	Water	Foam Spray	CO2	ABC Powder	Wet Chemical
Wood, paper and textiles	Safe for	Safe for	Not safe for	Safe for	Safe for
Flammable liquids	Not safe for	Safe for	Safe for	Safe for	Not safe for
Gaseous fires	Not safe for	Not safe for	Not safe for	Safe for	Not safe for
Cooking oils and deep fat fires	Not safe for	Not safe for	Not safe for	Not safe for	Safe for
Live electrical equipment	Not safe for	Not safe for	Safe for	Safe for	Not safe for

Figure 8 -Types of fire extinguishers

2.2.1.3 First aid management

Installation of first aid boxes at appropriate locations in the facility is required for immediate response to an accident. A first aid box contains, at minimum, the following items:

1. Bandages and/or dressings

2. Antiseptic cream or spray and disinfectant liquid

3. Sterile gauze pads and cotton swab or cotton wool

4. Burns dressing and gel

5. Adhesive tape and scissors

6. Disposable gloves

7. Pain-killer medicine (e.g. aspirin tablet)

For first aid boxes, the facility should also ensure the following:

- Clearly mark where the first aid box is placed and ensure that this is not locked and is easily accessible to workers.
- Inspect the first aid box at least monthly, replace used or expired items and update the inspection tag.
- Provide written first aid instructions in the local language near the first aid box.
- Place an incident logbook next to the first aid box to record any incidents.

2.2.1.4 Eye wash and body wash stands

For splashes of chemicals into the eyes or skin, it may be required to cleanse the affected area with water as quickly as possible to decrease the extent of the injury. For this, eye wash and body shower stations should be installed at key locations in the chemical stores and production areas with proper signages (see Figure 9) for easy identification. These stations should be:

- Reachable quickly (high hazard = closer distance).
- Placed in a well-lit area and identified with signage (see figure below).
- Located on the same floor level as the hazard area.
- Functioning with an adequate supply of water at the right temperature and pressure.

Figure 9: Signage for eye wash station and eyewash stand

2.2.1.5 Spill kit

Spill control kits should contain:

- sawdust, sand or any other absorbent container to absorb the liquid spill,
- broom, shovel and PPE needed,
- an empty container marked “hazardous waste”,
- a trolley to keep these items (for taking them quickly to the spillage place).

The procedure for containing spillage is as follows:

- Communicate the spillage to the store’s person in charge.
- Move the spill kit to the emergency site immediately.
- Sprinkle sand or other absorbent material around the outskirts of the spill area to stop the flow or spread in case of a liquid spill.
- Sprinkle absorbent material on the complete area of the spill to absorb the spill.
- Use the broom and shovel to collect the material containing the spilt chemical (waste), wearing PPE.
- Transfer the collected waste to the plastic container marked “hazardous waste”.
- Send the spilt waste to a hazardous waste storage area for disposal to an authorised third-party waste contractor.
- Return the spill kit to the allocated place at the Stores

2.2.2 Chemical labelling

Labels are a quick way to convey chemical safety information to staff using simple and understandable words (in English and local or official language) and pictograms for hazard characteristics and safe handling requirements. Every single chemical container in the manufacturing facility should be clearly identified with printed labels on the containers.

- Hazards of the chemical should be communicated through labels on the chemical container.
- Actions on chemical labelling are implemented.

2.2.2.1 Communication of hazards through labels on containers

Hazards should be communicated through labels on containers as per the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) system of labelling

GHS guidelines for labels on chemical containers have five label elements:[7]

1. Product Identifier

This is the name of the chemical product, which is the same as mentioned in the SDS. The supplier uses this name in their purchase contracts with the chemical formulator.

2. Signal Word

A signal word is used to "signal" the relative level of severity of the hazard to the reader of the label. The signal words used in the GHS are "Danger" and "Warning".

- Danger is mostly used for the more severe hazard categories.
- Warning is mostly used for the less severe hazard categories.

3. Hazard Pictogram

These are images that convey the hazard pictorially. GHS has harmonised hazards into nine pictograms. Each pictogram is an image inside a red diamond on a white background. The pictogram is related to the hazard class and category of classification as per the GHS, which is conveyed through the Hazard or H-Statement(s).

4. Hazard Statement(s)

GHS has harmonised all physical, health and environmental hazards into standardised statements called Hazard or H-Statements. These are arranged in codes followed by a description of the hazard.

5. Precautionary Statement(s):

Information on precautions to be taken for each H-Statement is described in the Precautionary or P-Statements. These are also arranged in codes, with a description of the precautions against each code. The GHS label for the chemical container should include appropriate precautionary information for the H-Statements mentioned.

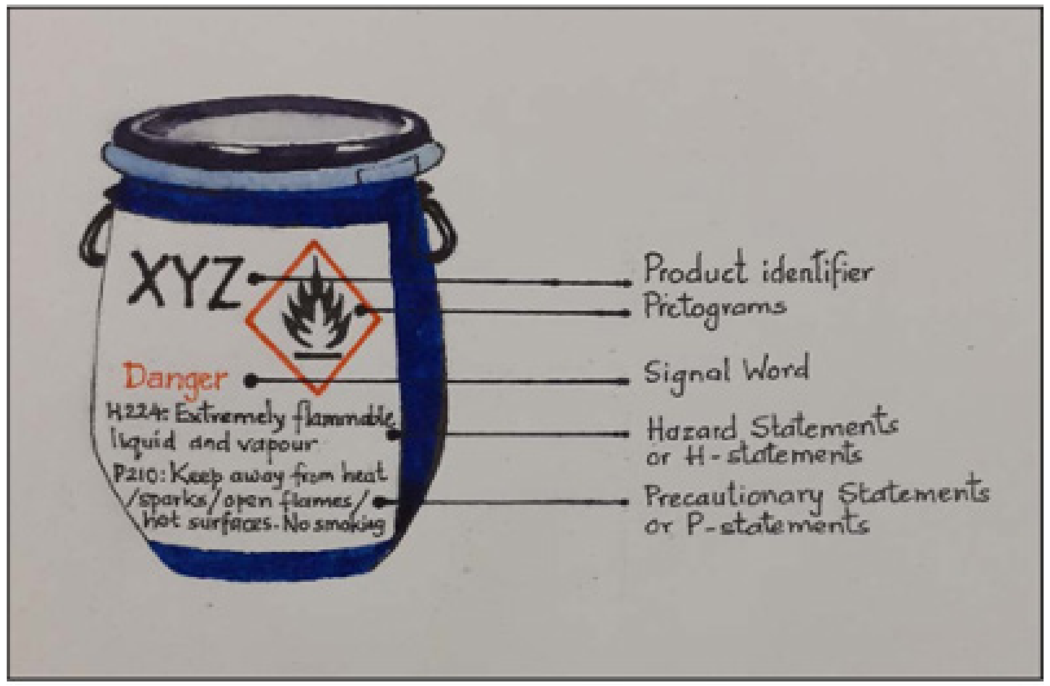


Figure 10: GHS label elements on a chemical container

Other information that is important to be stated on the label

ZDHC finds additional elements, besides the GHS label requirements, are important to be present on each label:

- The name, address and contact details of the chemical formulator
- Lot number or batch number (for traceability) (minimum requirement)
- Date of manufacture and end-of-life (expiry) date (recommended)

2.2.2.2 Actions for chemical labelling

Refer to the table below for checkpoints and actions for chemical labelling

Table 5: Chemical Labelling Actions

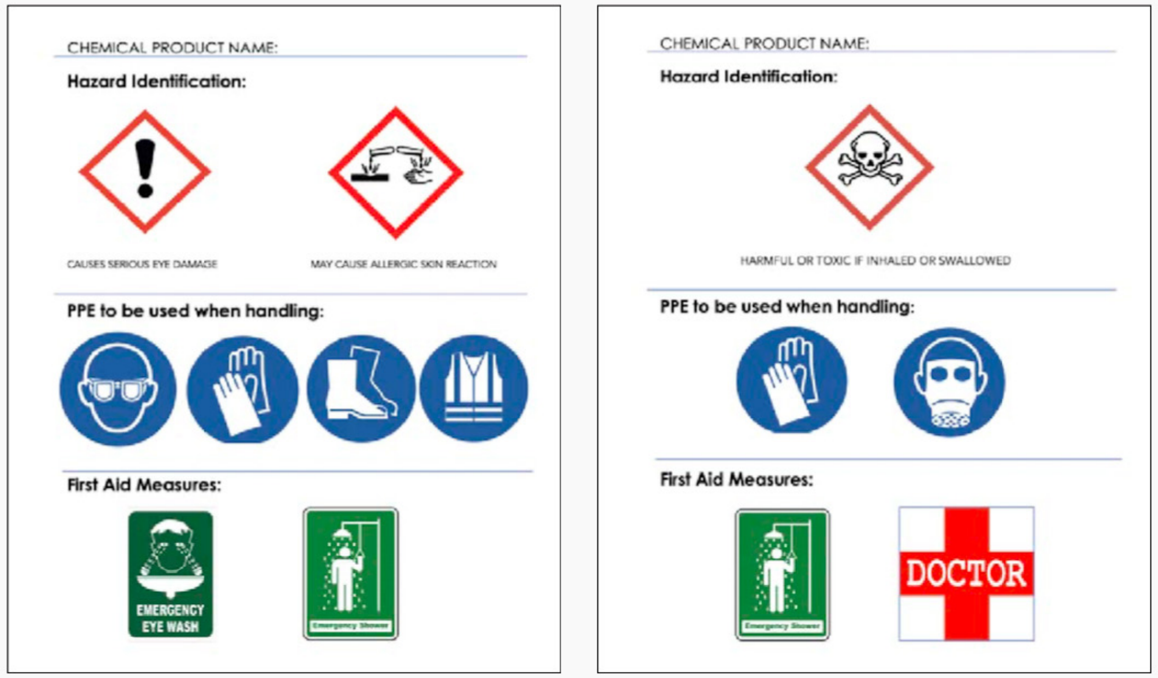
Checkpoint	Actions
Chemical container	• Check that the original label includes all the GHS label elements. • Ensure lot no./batch no. information is present on the label for complete traceability of the product. • Confirm that the product identifier on the label matches the product name in section 1 of the chemical's SDS. • Signal word, pictogram, hazard and precautionary statements, given on the label should match with the information provided in Section 2 of the SDS.

Table 5: Chemical Labelling Actions

Checkpoint	Actions
Information on labels	▪ Check that the original label includes all the GHS label elements. ▪ Ensure lot no./batch no. information is present on the label for complete traceability of the product. ▪ Confirm that the product identifier on the label matches the product name in section 1 of the chemical's SDS. Signal word, pictogram, hazard and precautionary statements, given on the label should match with information provided in Section 2 of the SDS.

2.2.3 Preparation and display of Chemical Safety Cards

Important hazard information and first aid/emergency response measures can be conveyed to workers handling chemicals using pictorial signs for quick understanding by preparing "Chemical Safety Cards". These cards can be kept near the chemical storage area for easy visibility to workers handling the chemical so that they can take necessary precautionary actions accordingly.



Chemical Safety Card for chemical product hazardous to eyes and skin

Chemical Safety Card for chemical product harmful or toxic if inhaled

Figure 11: Examples of Chemical Safety Sheets for display near the chemical storage area for each chemical product

2.3 Chemical handling and worker safety

(voluntary requirement)

- Implement engineering and administrative controls.
- Plan and enforce appropriate PPE requirements for workers.

2.3.1 Engineering and administrative controls

Engineering controls are physical controls that can help reduce exposure to chemicals. Administrative controls are work practices or procedures to reduce/eliminate chemical exposure of staff and manage the way they work.

2.3.1.1 Engineering controls

These strategies are designed to reduce workers' exposure to chemicals by placing a barrier between them and the hazard or by removing the hazard through ventilation. These controls involve physical modifications to the workplace rather than depending on workers' behaviour or the use of personal protective equipment (PPE).

Some examples of engineering controls that can be implemented at a facility:

- Install local exhaust ventilation (LEV) systems in areas with high exposure risks.
- Set up isolated or cordoned-off areas or booths for processes with high volatile emissions.

Always refer to a GHS-compliant SDS, Section 8.2.1, to understand the engineering controls required for a chemical product.

2.3.1.2 Specific engineering controls for solvents

Workers can be exposed to solvents during working hours due to leakages or evaporation losses. The engineering controls should effectively collect the exhaust gases while following the local norms for fugitive emission of VOCs.

Some recommended engineering controls for the use of solvents include:

- Using automated dispensing, handling, collecting and discharging system.

- Separating the solvent and workers by enclosing or isolating the task and using local exhaust ventilation (LEV) to minimise the vapour concentration in a worker's breathing zone.
- The workers in this isolated work area should use appropriate PPE for inhalation.
- LEVs can include:
    - Capture hood and duct systems to remove solvent vapours.
    - Increasing supply of fresh air to the isolated work area.
    - Enclosure of the process in a dedicated work area with zero exposure of the worker.
    - Regular maintenance and inspection of equipment and pipelines to prevent leaks and prompt repair for any leak detections.

2.3.1.3 Administrative controls

These involve work practices or procedures to minimise or eliminate staff exposure to chemicals and manage their work processes.

Examples of administrative controls that can be implemented at a facility are:

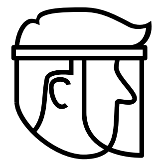
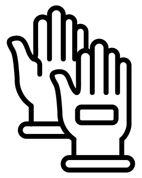
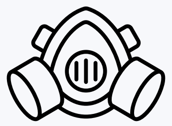
- Rotating staff/tasks to limit exposure time in chemical areas.
- Restricting the tasks only to qualified and trained personnel.
- Restrict access to chemical product storage areas to authorised staff only.
- Provide adequate hygiene facilities such as wash stations.
- Offer regular training to staff on hazards and safe handling of chemical products, label and hazard symbol recognition, spill management and/or PPE use.
- Implement a preventative maintenance programme for all process machinery.

2.3.2 PPE requirements for workers

Personal protective equipment (PPE) should be used for protection against accidents and incidents that may occur despite appropriate exposure control systems and operational procedures.

A proper inventory of PPE should be maintained by the Chemical Responsible Person. PPE required for the prevention of different exposures is mentioned in the below table.

Table 6: PPE Required for Different Exposure

	Type of Protection	Exposure Route	PPE Examples
	Eye and face protection	Oral, dermal	Safety glasses, goggles, face shields etc.
	Skin protection	Dermal	Chemical resistant footwear (shoes/boots/wellingtons), Clothing (aprons/suits)
	Hand protection	Dermal, oral	Gloves or gauntlets, disposable or otherwise, which are suitable for the job
	Respiratory protection	Inhalation	Respirators, masks or hoods that give adequate protection

PPE must be selected based on a formal job hazard review that identifies the specific chemical or physical hazards associated with the work task and the proper type of PPE.

Complete information on PPE recommendations and selection for a chemical can be found in Section 8 of a GHS (or equivalent) SDS.

2.3.2.1 Important considerations for PPE

- Identify all types of PPE needed in the facility.
- Select PPE appropriate to multiple chemical-related tasks to avoid staff having to add or change it mid-task.
- If possible, segregate chemical storage according to the PPE required to handle the chemical. This will help staff understand and use appropriate PPE.

- PPE is personal equipment. Each person responsible for handling chemicals should be provided with their own PPE, which should not be shared.
- PPE should be provided and maintained by the employer at no cost to the employee.
- PPE should be checked regularly for damage, contamination or wear-and-tear and replaced with new where applicable.

2.3.2.2 PPE for hand protection

Impervious gloves protect the hands of staff from the absorption of chemicals through the skin. Chemical-resistant gloves are typically made of:

- Rubber gloves (natural, butyl, neoprene, nitrile and fluorocarbon (Viton)
- Plastic gloves (polyvinyl chloride (PVC), polyvinyl alcohol and polyethylene)
- Gloves of blended or laminated material for better performance.

Table 7: PPE for Hand Protection

Latex (natural rubber)	Nitrile Rubber	Butyl Rubber	Neoprene	Norfoil
				
Low chemical-resistance. Suitable for general cleaning. Do not use to handle chemicals	Protects against oil, grease, some acids, bases and some solvents Do not use when working with oxidising agents, strong organic solvents.	Protects against peroxides, acids, bases and alcohols Do not use working with halogenated solvents or petroleum-based products.	Protects against gasoline, some alcohols, hydraulic fluids, organic acids and alkaline Do not use working with strong organic solvents	Applicable for most hazardous chemicals.

2.3.2.3 PPE for respiratory protection

This prevents inhalation of harmful airborne substances or volatile compounds emitted from chemical products during application or handling. Respirators are selected based on staff exposure results in terms of time and extent of exposure, as well as regular testing of air samples to monitor conformance to occupational exposure limits.

The different types of respirators are:

- N95 dust mask: This mask can be used if there are no oil-based particulates in the environment. It helps to filter 95% of 0.3-micron particles from the air. Some N95 masks come with a valve option that helps to reduce breathing resistance during exhalation.
- Air purifying respirator (APR): This type of respirator has an air-purifying filter, cartridge or canister in the face mask that removes specific air contaminants, such as particulates, gases, vapours, or both, from the air. There are two types: half-face masks and full-face masks. Filters/cartridges should be replaced after a certain period of use.
- Supplied air respirators (SAR): Provide clean, breathing air from an uncontaminated source (independent supply).

Figure 12: Full-face mask, supplied air respirators (SAR), half-face mask, dust mask, air-purifying respirators (APR)

2.3.2.4 PPE specifications when handling solvents

When handling solvents in the facility, the use of PPE with the appropriate CE marking in compliance with Regulation (EU) 2016/425 is advised as a preventive precaution. The table below details these technical specifications:

Table 8: Selection of PPE for Solvent Usage

PPE For	Description	Labelling	CEN Standard
Respiratory protection	Filter mask for gases and vapours.	CE CAT-III	EN 405:2002+A1:2010
Hands protection	Chemical protective gloves (Material: linear low-density polyethylene (LLDPE), Breakthrough time: > 480 min, Thickness: 0.062 mm)	CE CAT-III	EN ISO 374- 1:2016+A1:2018 EN 16523- 1:2015+A1:2018 EN ISO 21420:2020
Eye and face protection	Face shield	CE CAT-II	EN 166:2002 EN 167:2002 EN 168:2002 EN ISO 4007:2018
Body protection	Disposable clothing for protection against chemical risks	CE CAT-III	EN 13034:2005+A1:2009 EN 168:2002 EN ISO 13982- 1:2004/ A1:2010 EN ISO 6529:2013 EN ISO 6530:2005 EN 464:1994
Foot protection	Safety footwear for protection against chemical risk, with antistatic and heat-resistant properties	CE CAT-III	ENISO13287:2020 EN ISO 20345:2011 EN 13832-1:2019

2.4 Training plan for chemical management

(voluntary requirement)

- Training should be provided to all relevant employees and downstream suppliers regarding sustainable chemical management.
- At a minimum, the relevant employees shall be trained in the following:
  - RSL/ZDHC MRSL risk assessment,
  - use of personal protective equipment (PPE),

  - emergency procedures as per Standard Operating Procedure (SOP),
  - Safety Data Sheets,
  - safe storage and handling of chemicals,
  - wastewater and sludge management.

A training plan should be prepared through an evaluation of the questions below:

Whom to train?	What to train?
• Staff who handle chemicals and waste • Staff exposed to chemicals during use • Purchase/maintenance staff • Contractors and suppliers • Managers	• Safe handling and storage • PPE and engineering controls • Transfer of chemicals • Restricted substances (MRSL/RSL) • SDS • SOPs on chemical management • Emergency response measures
When to train?	**How to train?**
• At time of joining (new staff) • Refresher training for existing staff • New buyer requirements are to be communicated • Change in chemical management system	• Through internal trainer • Mock drills • Attending external workshops • Arranging on-site workshops • Online training webinars

The following points may be considered for the training of employees in sustainable chemical management:

- Encourage relevant staff to undergo training through the ZDHC Academy on sustainable chemical management training modules.
- Conduct in-house training workshops for different departments as needed through external experts. Experts approved by the ZDHC Academy.
- The Personnel/HR department must document all training provided and keep records of the date of training, name of trainer and trainees and training topic.
- The HR department should conduct and record physical mock drills for first aid, firefighting and emergency response measures.

CHAPTER 3:

Output Management

Output management focuses on ensuring that the environmental impacts of the recycled polyester manufacturing process are monitored and continuously improved. The requirements for output management are:

- Wastewater discharge and sludge
- Air emissions

3.1 Wastewater discharge and sludge

Mandatory requirements for wastewater discharge and sludge

A) Compliance with local regulations:

Facilities are expected to meet local regulations for wastewater parameters mandated by local legal authorities to ensure that their wastewater discharged to the receiving environment does not compromise the quality of the receiving environment.

> *Note: It is not the intent of the ZDHC Foundation to act as an agency reporting wastewater and sludge discharge data to governments or authorities having jurisdiction. It is expected that suppliers are accountable for reporting on their wastewater and sludge discharges, in accordance with applicable laws.*

B) Wastewater testing and reporting

Facilities should:

- Test wastewater for conventional parameters and heavy metals mentioned in Tables 10 and 11.
- Undertake a Root Cause Analysis and a Corrective Action Plan for any non-conformities detected and upload it to the ZDHC platform.

- Report the wastewater test data on the ZDHC platform.

> *Note: Wastewater testing and conformance requirements for recycled polyester manufacturing facilities do not depend on the volume of wastewater generated as outlined in the ZDHC Wastewater Guidelines V2.2. Even if generated wastewater is less than 15m³ per day, all parameters mentioned under Tables 10 and 11 are applicable for a recycled polyester facility.*

C) Sludge management

Facilities should:

- Meet the local regulations for sludge testing (if any) and disposal.
- Report the major sludge disposal pathway* used on the ZDHC platform.

* *Refer to the* ***ZDHC Sludge Reference Document*** *for a detailed description of the seven sludge disposal pathways that a manufacturing facility can use to dispose of its sludge. The manufacturer should maintain relevant information on the disposal pathway used.*

3.1.1 Wastewater and sludge conformance as per the discharge type

Recycled polyester manufacturing facilities should sample and test wastewater according to the below table.

Table 9: Testing Requirements for Recycled Polyester Manufacturing Facilities

Test Parameters and Sample Locations/ Discharge Types	ZDHC Conventional Parameters Testing and Reporting in Discharged Wastewater	ZDHC Heavy Metals Testing and Reporting in Discharged Wastewater	ZDHC Sludge Meet the Local Regulations and Report the Major Sludge Disposal Pathway
Direct	✓	✓	✓
Indirect with pretreatment[a] (with sludge)	✗	✓ Test only antimony, arsenic, cadmium, chromium (VI), lead, mercury	✓
Indirect with pretreatment[a] (without sludge)	✗	✓ Test only antimony, arsenic, cadmium, chromium (VI), lead, mercury	✗
Indirect without pretreatment[a]	✗	✓ Test only antimony, arsenic, cadmium, chromium (VI), lead, mercury*	✗
Zero Liquid Discharge (ZLD)	✗	✗	✓

* *For indirect facilities without pretreatment discharge type, ZDHC heavy metals (antimony, arsenic, cadmium, chromium (VI), lead and mercury) as explained in the above table should be sampled and tested only in untreated wastewater as there is no pretreatment involved.*

Note: a: Any process or operation carried out to treat the wastewater prior to discharge to the CETP.

Untreated Wastewater ('Raw wastewater'): *Wastewater that is collected prior to any treatment.*

Sludge — *The residual solid, semisolid, or slurry material generated as a by-product of wastewater treatment processes, including primary, secondary and tertiary (ZLD) treatments.*

Discharged wastewater (Effluent): *Treated wastewater that is discharged to the environment or partially treated or untreated wastewater that is discharged to a Central Effluent Treatment Plant (CETP) for further treatment. (This is not applicable to indirect discharge without pretreatment as well as to zero liquid discharge facilities)*

3.1.2 ZDHC conventional parameters for wastewater

Global legislation has traditionally used conventional parameters to describe and regulate wastewater quality. These parameters, their limit values and recommended standard test methods for analysis are defined in Table 10.

These parameters are applicable only to direct discharge type facilities.

Table 10: ZDHC Conventional Parameters for Wastewater

Parameters	Unit of Measurement	Maximum Allowable Limit	Standard Methods for Analysis and Testing Equivalent Methods Can Be Used, Must Be First Communicated to and Approved by ZDHC			
			International/ Europe	United States	China	India
pH	pH	6-9	ISO 10523	US EPA 150.1 SM 4500-H+	HJ1147	IS 3025 (Part 11) Electrometric method only
Temperature difference[a]	°C	Δ+15	DIN 38 404-4 or equivalent	US EPA 170.1 SM 2550	GB/T 13195	IS 3025 (Part 9)
[a] Take the temperature of the discharged wastewater and the receiving body of water upstream. The temperature of the receiving body is subtracted from the temperature of the discharged wastewater to give the delta temperature difference, which can be a positive or a negative value. The discharge limits only refer to a positive value, which produces an overall increase in the temperature of the receiving body of water. This parameter is measured on-site by the sampler and is applicable only for direct discharge. *a. There may be situations where the sampler is not able to measure the temperature of the receiving body. These situations may include:* *- The receiving body may be several kilometres away from the point of discharge and the facility is discharging the effluent into the receiving body through a pipeline.* *- Accessing the location of the receiving body to measure its temperature can be risky in terms of injury to the sampler or damage to equipment.* *- The effluent is discharged directly into the ground.* In all such cases where the access to the receiving body is not possible or unsafe, the laboratory should report this parameter as "Not Applicable".						
Colour (436nm; 525; 620nm)	m-1	7; 5; 3	ISO 7887-B			
Persistent foam[b]	Absent / present	No indication of persistent foam in receiving water	N/A	N/A	N/A	N/A
b. Foam is a naturally occurring phenomenon in aeration basins in which biological wastewater treatment occurs. Samplers should include photographs of the foam they witnessed in the final lab report, along with the time and date of taking photos. The foam colour should be similar to the liquid in the aeration basin, dissipate quickly and be contained within the aeration basin. For direct discharge facilities, samplers should check for persistent foam on the surface of receiving waters at the point of discharge and the presence or absence of foam should be noted. This should be checked at the same location used for sampling the temperature difference. This test is to be done on-site by the sampler. In case the receiving body is not accessible or risky for the sample to access, a visual estimation of the foam in the aeration basin should be done. If the foam is above 45 centimetres in height (by visual estimation) then it could result in permanent foam being discharged onto the surface of receiving waters and should be reported as 'fail' for foam parameter.						
Ammonium-Nitrogen	mg/L	10	ISO 11732 ISO 7150	US EPA 350.1 US EPA 350.3 SM 4500 NH3 - D, E, F, G, or H	HJ 535	IS 3025 (Part 34) phenate or ammonia selective electrode only

Table 10: ZDHC Conventional Parameters for Wastewater

Parameters	Unit of Measurement	Maximum Allowable Limit	Standard Methods for Analysis and Testing Equivalent Methods Can Be Used, Must Be First Communicated to and Approved by ZDHC			
			International/ Europe	United States	China	India
AOX	mg/L	3	ISO 9562	US EPA 1650	HJ/T 83-2001	
Biochemical Oxygen Demand 5-days concentration (BOD5)	mg/L	30	ISO 5815-1	US EPA 405.1 SM 5210-B	HJ 505	IS 3035 (Part 44) seeded dilution water (BOD5)
Chemical Oxygen Demand (COD)	mg/L	150	ISO 6060 ISO 15705	US EPA 410.4 SM 5220-D	HJ 828 GB/T 11914 e	IS 3025 (Part 58) e
Dissolved Oxygen (DO)[c]	mg/L	≥ 4	ISO 5814	EPA 360.1 SM 4500-O-G	HJ 506	
Oil and grease	mg/L	10	ISO 9377-2	SM 5520-B/C; US EPA 1664 revision B	HJ 637 (total oil and grease)	IS 3025 (Part 39) partition gravimetric or partition Infra-red
Total Phenols / phenol index	mg/L	0.5	ISO 6439	SM 5530-B/C	HJ 503 must meet the required reporting limit	IS 3025 (Part 43)
Total Dissolved Solids (TDS)	mg/L	Sample and Report		SM 2540-C USEPA 160.1	GB/T 5750.4-2013 180°C (180 degree centigrade)	IS 3025 (Part 16) 179°C to 181°C
Total Nitrogen	mg/L	20	ISO 11905 - Part 1 ISO 29441	USEPA 351.2 SM 4500P-J SM 4500N-B SM 4500N-C	HJ 636	IS 3025 (Part 34) measure and total all forms of nitrogen (ammonia, nitrate, nitrite, organic)
Total Phosphorus	mg/L	3	ISO 17294 ISO 11885 ISO 6878	USEPA 365.4 SM 4500P-J USEPA 200.7 USEPA 200.8 USEPA 6010C USEPA 6020A	GB/T 11893	IS 3025 (Part 31) IS 3025 (Part 65)
Total Suspended Solids (TSS)	mg/L	50	ISO 11923	USEPA 160.2 SM 2540D	GB/T 11901	IS 3025 (Part 17) 103°C to 105°C

c) *For direct discharge type of facilities the following parameters must be measured on-site every hour by the sampler during the composite sampling: pH, temperature difference, persistent foam, and dissolved oxygen. Refer to the* **ZDHC Wastewater and Sludge Laboratory Sampling and Analysis Plan** *for more information.*

3.1.3 ZDHC heavy metals wastewater parameters

Heavy metals are often included in legally mandated standards and are, therefore, listed separately in this section. Table 11 defines these parameters and recommended standard test methods for analysis.

Table 11: ZDHC Heavy Metals Wastewater Parameters

Parameter	Unit	Requirements	Standard Methods for Analysis and Testing Equivalent Methods Can Be Used, Must Be First Communicated to and Approved by ZDHC			
			International/Europe	United States	China	India
Antimony	mg/L	Sample and report only	ISO 17294	USEPA 200.8 USEPA 6010C USEPA 6020A	HJ 700	IS 3025 (Part 65)
Chromium (VI)	mg/L	Sample and report only	ISO 18412	US EPA 218.6	GB 7467	IS 3025 (Part 52) must meet reporting limit
Arsenic	mg/L	Sample and report only	ISO 17294	US EPA 200.8 US EPA 6010C US EPA 6020A	HJ 700	IS 3025 (Part 65)
Chromium, total	mg/L	Sample and report only	ISO 17294	US EPA 200.8 US EPA 6010C US EPA 6020A	HJ 700	IS 3025 (Part 65)
Cobalt	mg/L	Sample and report only	ISO 17294	U SEPA 200.8 US EPA 6010C US EPA 6020A	HJ 700	IS 3025 (Part 65)
Cadmium	mg/L	Sample and report only	ISO 17294	US EPA 200.8 US EPA 6010C US EPA 6020A	GB 7475 HJ 700	IS 3025 (Part 65) IS 3025 (Part 41) AAS Instrumental Method
Copper	mg/L	Sample and report only	ISO 17294	US EPA 200.8 US EPA 6010C US EPA 6020A	GB 7475 HJ 700	IS 3025 (Part 65) IS 3025 (Part 42) AAS Instrumental Method
Lead	mg/L	Sample and report only	ISO 17294	USEPA 200.8 US EPA 6010C US EPA 6020A	GB 7475 HJ 700	IS 3025 (Part 65) IS 3025 (Part 47) AAS Instrumental Method

Table 11: ZDHC Heavy Metals Wastewater Parameters

Parameter	Unit	Requirements	Standard Methods for Analysis and Testing Equivalent Methods Can Be Used, Must Be First Communicated to and Approved by ZDHC			
			International/Europe	United States	China	India
Nickel	mg/L	Sample and report only	ISO 17294	US EPA 200.8 US EPA 6010C US EPA 6020A	GB 11912 HJ 700	IS 3025 (Part 65) IS 3025 (Part 54) AAS Instrumental Method
Zinc	mg/L	Sample and report only	ISO 17294	USEPA 200.8 US EPA 6010C US EPA 6020A	GB 7472 GB7475 HJ 700	IS 3025 (Part 65) IS 3025 (Part 49) AAS Instrumental Method
Mercury	mg/L	Sample and report only	ISO 17294 ISO 11885	EPA 200.8-SIM EPA 6020A-SIM EPA 245.1 EPA 245.7	HJ 597 HJ694	IS 3025 (Part 48) Cold Vapor AAS only IS 3025 (Part 65) [SIM]

Note: Limit values for heavy metals will be included in the next update of these guidelines

3.1.4 Sludge management

Facilities must comply with the existing local legal regulations for the treatment and handling of industrial wastewater sludge and should report the major sludge disposal pathway used on the ZDHC platform.

Polyester recycling facilities are expected to maintain information and records of their major sludge disposal pathway, along with the sludge manifest required for legal purposes. In cases where sludge is disposed of via authorised third-party waste contractors, suppliers should make an effort to get all relevant information on the disposal pathway from the waste contractor.

The following section includes declaration templates that suppliers should use to enter information for each disposal pathway. After inputting the information relevant to the supplier's major disposal pathway, the supplier should sign and give details of the signing authority and date in the declaration.

These declarations will be collected by samplers during the wastewater sampling and submitted to their lab.

- Declaration for ZDHC Sludge Disposal Pathway A
- Declaration for ZDHC Sludge Disposal Pathway B
- Declaration for ZDHC Sludge Disposal Pathway C
- Declaration for ZDHC Sludge Disposal Pathway D
- Declaration for ZDHC Sludge Disposal Pathway E
- Declaration for ZDHC Sludge Disposal Pathway F
- Declaration for ZDHC Sludge Disposal Pathway G

Disposal pathways

The ZDHC Sludge Reference Document v1.0 details seven disposal pathways for sludge:

- Pathway A – On-site or Off-site incineration at >1000'C
- Pathway B - Landfill with significant control measures
- Disposal Pathway C - Building products processed at >1000'C
- Disposal Pathway D - Landfill with limited control measures
- Disposal Pathway E - Off-site incineration and building products processed at <1000'C

- Disposal Pathway F - Landfills with no control measures
- Disposal Pathway G - Land application for a specific purpose in approved areas.

Note: Sludge testing will be included in the next update of these guidelines.

3.2 Air emissions

Mandatory requirements for air emissions

Each polyester recycling process, mechanical, thermomechanical, hydrothermal and various chemical recycling, has distinct air emissions and associated impacts, therefore, suppliers should follow the below requirements for air emissions:

A) Compliance with local regulations:

- Have a valid licence to operate.
- Quantify, track and report emissions of all parameters, consistent with applicable local regulations.

Note: It is not the intent of ZDHC to act as an agency reporting air emissions to governments or authorities having jurisdiction. It is expected that suppliers are accountable for reporting their air emissions, in accordance with applicable laws.

B) Quantify, track and report GHG and VOC emissions on the ZDHC platform

- Mechanical, thermomechanical and hydrothermal recycling facilities
  - GHG (Scope 1 and Scope 2) emissions - Use existing GHG (Scope 1 and Scope 2) emissions calculation platforms that are recognised and align with GHG Protocol standards.
- Chemical recycling facilities
  - GHG (Scope 1 and Scope 2) emissions - Use existing GHG (Scope 1 and Scope 2 emissions) calculation platforms that are recognised and align with GHG Protocol standards.

- VOC emissions (methanol, ethylene glycol, acetaldehyde and non-methane total hydrocarbons). Monitor VOC emissions at the exhaust point of the recycling process, waste gas, spinning and solvent recovery unit.

  One of the following monitoring methods can be employed to measure ambient VOC emissions.

  - **Fixed or mobile air quality monitoring stations:** Fixed or mobile air quality monitoring stations placed around the facility and in surrounding areas can be used to assess the impact of emissions from the recycling facility on the local environment.
  - **Real-time monitoring:** Periodic sampling and testing by an ISO 17025 accredited third-party laboratory is recommended. Standard test methods shall be chosen for the manufacturing region. In the absence of local or regional test methods, internationally recognised test methods, often recommended by governmental organisations such as the ISO, EPA or GB, ASTM shall be used.
  - **Air dispersion modelling:** This can be used to assess ambient air emissions. Based on emission data, meteorological conditions and topographical features, it uses mathematical simulations to predict how pollutants disperse in the atmosphere.
  - Authorised data from the local governing body/regulatory authorities.

Recycled polyester facilities should report GHG and VOC emissions data (as applicable) for the calendar year (1st January to 31st December) on a ZDHC platform.

Note: In the initial phase, ZDHC Recycled Polyester Guidelines V1.0 focuses on the data collection for GHGs (Scope 1 and Scope 2 emissions) and VOCs emissions only and requires its recycled polyester suppliers to report it on the ZDHC platform.

APPENDIX A

Polyester Recycling Processes

Polyester recycling technologies focus on converting post-consumer (discarded) PET bottles and pre- and post-consumer textile PET waste and other polyester products into polyester fibres.

The main recycling methods are:

- Mechanical and thermomechanical recycling, which involves cleaning, shredding and melting the plastic to form new fibres.
- Hydrothermal recycling focuses on recycling polyester and cellulose from polyester-cotton blends using hydrothermal and dissolution treatments.
- Chemical recycling, which breaks down or depolymerises the PET into its monomers to be re-polymerised into new polyester.

1.1 Mechanical and thermomechanical recycling

Mechanical and thermomechanical recycling, or physical recycling of thermoplastics like PET, entails several steps: sorting the plastic waste, separating and removing contaminants and then crushing, grinding, or shredding the plastic to reduce its size. Following this, the processed plastic is melted down and sometimes mixed with additives, then extruded into resin pellets or spun into a polyester yarn.

Steps in polyester mechanical and thermomechanical recycling

- **Collection:**
  - Pre-consumer and post-consumer polyester waste, such as PET bottles, packaging and textile materials are collected.

- **Sorting:**
  - Collected material is sorted to separate polyester from other materials, including non-PET plastics (e.g. segregating and removing polycarbonate bottles to avoid BPA contamination), metals and other contaminants.

- **Cleaning:**
  - The sorted polyester waste is thoroughly cleaned to remove dirt and labels, ensuring the feedstock is as clean as possible for further processing.
- **Shredding:**
  - The cleaned polyester is shredded into smaller flakes or chips to be prepared for reprocessing.
- **Melting:**
  - Shredded polyester flakes are melted in an extruder at controlled temperatures to avoid thermal degradation. If required, additives are added to improve the intrinsic viscosity.
- **Filtering:**
  - Molten polyester is filtered to remove any remaining impurities and contaminants, ensuring a purer output.
- **Re-extrusion:**
  - Filtered molten polyester is extruded into fibres, filaments, or pellets, depending on the desired end product.
- **Cooling:**
  - Extruded polyester is cooled to be solidified into the final shape, either fibre strands or plastic pellets.
  - Pelletising (if applicable):
  - If the goal is to produce pellets for later use, the cooled polyester is cut into small, uniform pellets.[8]

1.2 Hydrothermal recycling

This recycling process is designed to separate polyester and cellulose from cotton-polyester blends using hydrothermal and dissolution treatments. This process decomposes cotton into cellulose powder, allowing for the effective separation of polyester fibres while maintaining their quality for fibre-to-fibre recycling. The recovered cotton cellulose powder can be repurposed for re-spinning or used in agriculture.[9]

Below is a simplified sequence of the hydrothermal process:

Process sequence of the hydrothermal process.

- **Input of cotton-polyester blends:**
  - The process begins with the collection and preparation of textile waste composed of cotton and polyester blends.
  - Blended textiles, such as clothing or fabric scraps, are fed into the system.
- **Hydrothermal treatment:**
  - The textile waste undergoes hydrothermal treatment, where hot water is applied at a controlled temperature and pressure to break down the cotton component of the blend.
  - The cotton fibres are decomposed into cellulose powder, while the polyester fibres remain intact.
- **Separation of polyester and cellulose:**
  - After the hydrothermal treatment, the cotton (now in the form of cellulose) is separated from the polyester fibres.
- **Recovery of polyester fibres:**
  - The polyester fibres are recovered from the blend whilst maintaining their quality, making them suitable for fibre-to-fibre recycling.
  - The polyester can be repurposed to create new yarns and fabrics, allowing for circular textile production.
- **Cellulose powder utilisation:**
  - The cellulose powder, obtained from the decomposed cotton, can be used in applications such as re-spinning to create regenerated fibres or for agricultural purposes, such as soil enrichment.

1.3 Chemical recycling

Chemical recycling is a versatile process that can be applied to both PET bottles and textile waste, offering a solution for managing plastic and textile waste materials. This method involves breaking down PET into its fundamental monomers through chemical reactions. In the case of PET bottles, chemical recycling efficiently converts the plastic back into its raw components, which can be reused to produce high quality new bottles, other plastic products or textile yarn/filaments.

Similarly, chemical recycling can decompose polyester components of textile waste into their fundamental monomer, making it possible to recycle textiles often blended with other fibres. This helps reduce landfill waste and promotes a circular economy by enabling the continuous reuse of materials in the production cycle.

Chemical recycling includes various processes, such as:

- Glycolysis
- Glycolysis followed by transesterification
- Methanolysis
- Hydrolysis

Steps in polyester chemical recycling

- **Collection and sorting:**
    - Polyester waste, such as PET bottles or textiles, is collected and sorted to remove contaminants and non-polyester materials.
- **Cleaning:**
    - The sorted polyester waste is thoroughly cleaned to remove dirt, labels, adhesives and other impurities.
- **Shredding:**
    - The cleaned polyester waste is shredded into smaller flakes or pellets to facilitate the chemical recycling process.

- **Depolymerisation:**
    - The shredded polyester is chemically broken down into its monomer components through processes such as glycolysis, methanolysis, or hydrolysis. This involves the application of chemicals like glycol or methanol, often in the presence of a catalyst.
- **Purification:**
    - The resulting monomers, such as bis(2-hydroxyethyl) terephthalate (BHET) or dimethyl terephthalate (DMT), are purified to remove any residual impurities, ensuring they meet the quality standards for reuse.
- **Repolymerisation:**
    - The purified monomers are chemically reacted and re-polymerised to form new polyester polymers, which can then be used to produce new polyester fibres or other products.
- **Pelletisation:**
    - The re-polymerised polyester is cooled and formed into pellets or granules, which serve as raw material for the production of new polyester-based products.
- **Extrusion and product formation:**
    - The polyester pellets are melted and extruded to create fibres, films, or other polyester products, depending on the intended application.

1.3.1 Depolymerisation processes

1.3.1.1 Glycolysis

Glycolysis is a chemical recycling process used to depolymerise polyesters into their monomeric or oligomeric forms. It is primarily used for recycling high-quality PET bottles and can compete with mechanical recycling for raw materials.

In this process, waste polyester materials are treated with ethylene glycol, which breaks the ester bonds in the polyester, resulting in the formation of bis(2-hydroxyethyl) terephthalate (BHET) and other low molecular weight compounds through transesterification. The reaction occurs under pressure. Temperatures required for the reaction are in the range of 180–240 °C. A catalyst is needed to enhance the reaction rate for BHET production. Zinc acetate, when used as a catalyst in PET glycolysis, has been shown to yield the highest recovery of the BHET monomer compared to other metal acetates like lead, cobalt and manganese.[10, 11]

This depolymerisation process converts the solid polyester waste into a liquid or semi-solid state, which can be further purified and then repolymerised to produce new polyester. Here, resulting oligomers BHET and EG were recovered through distillation, molecular sieves and crystallisation. BHET was then repolymerised into PET and extruded into pellets.[3, 10, 11, 12]

1.3.1.2 Glycolysis followed by transesterification

This process involves two distinct stages to convert PET into valuable chemical intermediates.

- **Glycolysis stage:** The first stage is glycolysis, where PET waste is depolymerised. During this process, polyester reacts with ethylene glycol, breaking down the polymer chains to bis(2-hydroxyethyl) terephthalate (BHET).
- **Transesterification stage:** In the second stage, transesterification, BHET undergoes a reaction with methanol where hydroxyl groups of BHET react with methanol to form DMT and release ethylene glycol as a byproduct.

1.3.1.3 Methanolysis

Methanolysis is a transesterification between methanol and PET, in which PET can be broken down into DMT and EG through a reaction with methanol at high pressures (2–4 MPa) and elevated temperatures (180–280 °C). The products from methanolysis are typically isolated through distillation or crystallisation methods.

The resulting DMT can then be repolymerised into PET through two pathways:

- Transesterification of DMT with EG to form BHET, releasing methanol, followed by the reaction of BHET with the growing PET polymer chain to create longer-chain PET, releasing EG in the process.
- Hydrolysis of DMT to produce TPA and methanol, followed by the reaction of the recovered TPA with EG.[12]
- Catalysts used in the methanolysis process include zinc acetate, magnesium acetate, lead dioxide and cobalt acetate, with zinc acetate being the most commonly used. During depolymerisation, methanol is kept in its liquid state by maintaining high-pressure conditions. In addition to DMT and EG, the reaction can produce other compounds such as alcohols, glycols and phthalate derivatives.[4, 5, 6, 12]
- DMT produced through methanolysis is usually cleaner, with fewer physical contaminants than BHET, the monomer from PET glycolysis. However, it might still have some organic impurities that can cause slight discolouration.[4, 12]

1.3.1.4 Hydrolysis

Hydrolysis decomposes the ester bonds within the PET structure into terephthalic acid (TPA) and ethylene glycol (EG) through a reaction with water. The process involves high pressures of 1.4–2 MPa and temperatures ranging from 200–250 °C and can be conducted under acidic, basic, or neutral conditions. The three primary hydrolysis methods are:

Acid hydrolysis

Acid hydrolysis involves using various acids, such as concentrated sulfuric acid (H_2SO_4), nitric acid (HNO_3) and phosphoric acid (H_3PO_4). Concentrated sulfuric acid is the most commonly used because it reduces energy consumption by lowering the need for high pressure and temperature during the reaction.

The hydrolysis product is treated with sodium hydroxide to neutralise the TPA produced, which causes the formation of the corresponding TPA sodium salt, which is soluble in water.

In the final stage of the process, the solution is acidified once more to precipitate TA, which is then obtained with a purity of over 99%. However, a significant drawback of this method is the corrosive nature of the reaction mixture. It also generates a large amount of liquid waste containing inorganic salts and sulfuric acid, which requires proper disposal.[4, 12]

Alkaline hydrolysis

In the alkaline hydrolysis process, an aqueous solution (4-20%) of sodium hydroxide (NaOH) or potassium hydroxide (KOH) is used. The reaction takes place under pressure at temperatures between 200–250 °C for several hours. This process produces disodium or dipotassium terephthalate, which is then treated with sulfuric acid to extract TPA. The yield of TPA depends on the reaction temperature and the concentration of the catalyst used.[4, 12]

Neutral hydrolysis

Neutral hydrolysis involves using hot water or steam at temperatures between 200–300 °C and pressures ranging from 1–4 MPa. This method has been shown to produce high-purity TPA and EG monomers, with higher yields observed at temperatures above 250 °C.

Similar to alkaline hydrolysis, the yield of TPA and EG increases with higher reaction temperatures. This process breaks down PET without producing unwanted liquid waste containing inorganic salts. Additionally, while there is a slight drop in pH due to the formation of TPA, the reaction system remains non-corrosive.[4, 12]

In the hydrolysis process, the diluted EG produced can be recovered through extraction or distillation. Compared to acid and alkaline hydrolysis, neutral hydrolysis generates fewer inorganic salts, making it a more environmentally friendly option. However, a downside is that the TPA obtained through neutral hydrolysis is less pure than that from acid or alkaline methods, leading to impurities in the repolymerised PET. These contaminants can be removed by filtering the TPA solution.[12]

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