**Applicant:** ChemEverse

**Inventors:** Arsh Jaswal, Amish Verma,Om Singh, Yash Upadhyay.

**Chemical Product Formula:** CH2=C(R)-COO-(CH2CH2O)nR'

[R = H or $CH_3$ (from acrylic or methacrylic acid backbone)]

[R' = End group, often an alkyl or ether group]

**Chemical Product Name:** Polycarboxylate Ether (PCE)

**Process Title:** Safety Regulations and Waste Management in PCE production.

**EHS Summary:**

a. List the wastes generated and their quantity of generation.

## 1. Unreacted Raw Materials

| Material | Waste Quantity (kg/day) | Waste Output | Calculation Basis |
|---|---|---|---|
| Acrylic Acid (AA) | $12 \times 118.64 \div 1000 = 1.4237$ | Stream 802 | Unreacted AA from R101 |
| Methacrylic Acid (MA) | $14 \times 118.64 \div 1000 = 1.6610$ | Stream 802 | Unreacted MA from R101 |
| 3-Chloro-2-methyl-1-propene (CMP) | $9.5 \times 118.64 \div 1000 = 1.1271$ | Stream 802 | Unreacted CMP from R101 |

Table 1: Unreacted Raw Materials

## 2. Byproduct Streams

| Material | Waste Quantity (kg/day) | Waste Output | Notes |
|---|---|---|---|
| Water (from Esterification) | $57.6 \times 118.64 \div 1000 = 6.8336$ | Stream 603 | Byproduct water |
| Water (from Neutralization) | $18 \times 118.64 \div 1000 = 2.1355$ | Stream 603 | Reaction byproduct water |

Table 2: Byproduct Streams

## 3. Catalyst and Salt Waste

| Material | Waste Quantity (kg/day) | Waste Output | Notes |
|---|---|---|---|
| Potassium Carbonate ($K_2CO_3$) | $2.5 \times 118.64 \div 1000 = 0.2966$ | Stream 602 | Filtered out catalyst |
| Excess Methoxy Poly Ethylene Glycol (MPEG) | $2000 \times 118.64 \div 1000 = 237.28$ | Stream 802 | Unreacted MPEG |

Table 3: Catalyst and Salt Waste

## 4. Solvent Waste

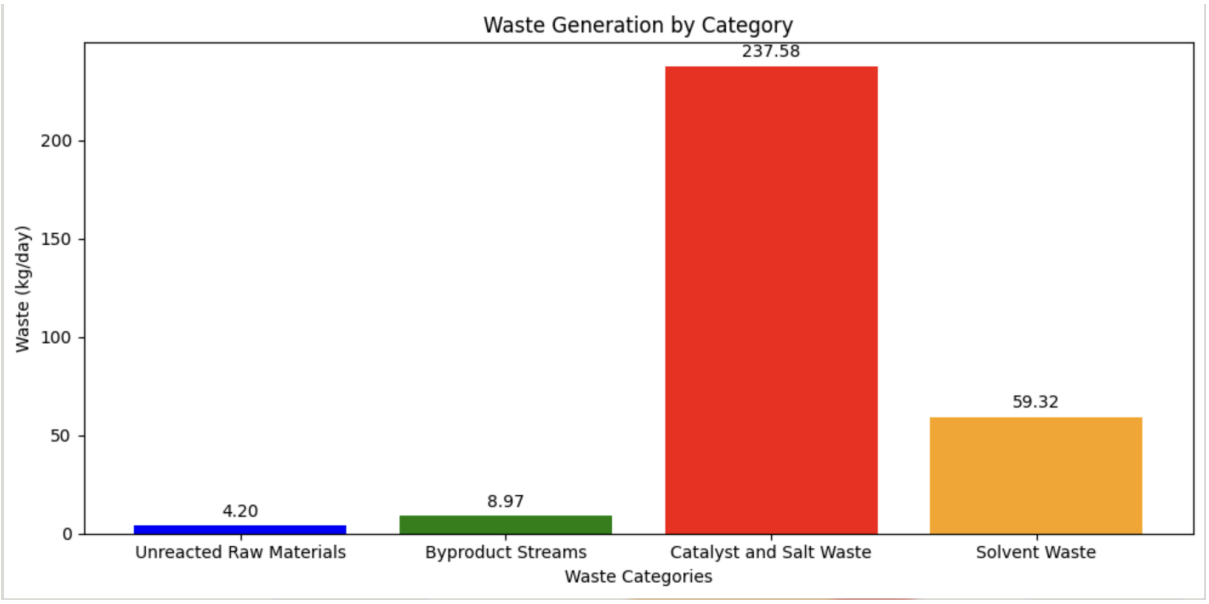
| Material | Waste Quantity (kg/day) | Waste Output | Notes |
|---|---|---|---|
| Ethanol | $500 \times 118.64 \div 1000 = 59.32$ | Stream 702 | Evaporated solvent |

Table 4: Solvent Waste

## Total Waste Generation Summary

| Waste Category | Total Waste (kg/day) |
|---|---|
| Unreacted Raw Materials | 4.19741 |
| Byproduct Water | 8.9691 |
| Catalyst and Salt Waste | 237.5766 |
| Solvent Waste | 59.32 |
| **Grand Total Waste** | **310.06311** |

Table 5: Total Waste Generation Summary



b. What are the current regulations for the above waste materials? (Limits to which it can be disposed in the environment)

**Disposal:** The above waste material can be disposed of in water bodies but should not exceed the limits.

- The CPCB has set a general threshold for COD in treated effluents at **250 mg/L.**
- The acceptable pH range is between 5.5 and 9.0.
- The BOD limit for discharge into surface waters is often set at 30 mg/l.

This is valid for all wastes mentioned.

| **Chemical** | **Safety Concerns** | **Limits** | **Additional Information** |
|---|---|---|---|
| **Ethanol Solvent** | Fire and explosion hazards, eye irritation, and narcotic effects on inhalation. | OSHA PEL: TWA 1000 ppm (1900 mg/$m^3$)<br><br>NIOSH REL: TWA 1000 ppm (1900 mg/$m^3$)<br><br>NIOSH IDLH: 3,300 ppm (10% of the lower explosive limit)<br><br>ACGIH TLV: STEL 1000 ppm | Ethanol is a highly flammable liquid and vapor.<br>Ethanol has a lower explosive limit (LEL) of 3.3% and an upper explosive limit (UEL) of 19%. Proper ventilation and grounding of equipment are essential to prevent static discharge and ignition. |
| **Methoxy Polyethylene Glycol** | Direct contact may cause mild irritation to the skin and eyes.<br>Inhalation of mists or vapors should be avoided. | Dowanol TMH is 13 µg/$m^3$ based on an annual averaging time. | White to pale yellow semi solid, soluble in water, with a boiling point of ~120°C. |

| | | | |
|---|---|---|---|
| **Acrylic Acid** | Causes severe irritation to the skin, eyes, and respiratory system. It may also cause sensitization and organ damage upon prolonged exposure. | NIOSH REL: 10 hours TWA of 2 ppm (6 mg/m$^3$)<br><br>ACGIH TLV: TWA of 2 ppm (5.9 mg/m$^3$)<br><br>Vacated 1989 OSHA PEL: TWA of 10 ppm (30 mg/cu m, skin designation, still enforced in some regions. | Acrylic acid is a flammable liquid, used in production of polymers. Acrylic acid has an LEL of 2.4% and a UEL of 8.02%. |
| **Methacrylic Acid** | highly corrosive to the eyes, skin, and respiratory tract. Inhalation can lead to lung edema. | NIOSH Recommended Exposure Limit (REL): 20 ppm (70 mg/m$^3$) TWA of 1 10 hours.<br><br>ACGIH Threshold Limit Value (TLV): 20 ppm as an 8-hour TWA. | Methacrylic acid is a colorless, corrosive liquid with a strong, acrid odor, commonly used in the production of polymers, coatings, and adhesives.<br><br>It has a flash point of approximately 67°C and an autoignition temperature of 365°C.<br><br>Its LEL is 1.6% by volume in air, while the UEL is 8.8%. |
| **3-Chloro-2-methyl -1-propene** | highly flammable, nose irritation, throat irritation, eye irritation, skin irritation (severe skin burns), damaging fertility or the unborn child, STOT, Toxic to aquatic life. | No Limits as such.<br><br>National Toxicology Program (NTP) LEL: 2.3% as per 1992<br><br>National Toxicology Program (NTP) UEL: 9.3% as per 1992 | 3-Chloro-2-methylpropene (CMP)is a clear, colorless liquid with a pungent odor, primarily used as an intermediate in organic synthesis.<br><br>It is highly flammable, with a flash point of -10°C, and can form explosive vapor-air mixtures. |

| | | | |
|---|---|---|---|
| **Potassium Carbonate** | May cause irritation to the respiratory system,causing serious eye and skin irritation. | No Limits as such. | Reaction with Acids: Reacts with acids to release carbon dioxide gas.<br>Corrosivity: When dissolved in water, the resulting solution is corrosive to aluminum and its alloys.<br>Solubility: Highly soluble in water, forming a strongly alkaline solution.<br>Hygroscopic Nature: Readily absorbs moisture from the air, which can lead to clumping if not stored properly. |

c. Describe the treatment procedure for wastes with a block diagram. Your chemical plant must be a zero liquid discharge plant.

# WASTE TREATMENT

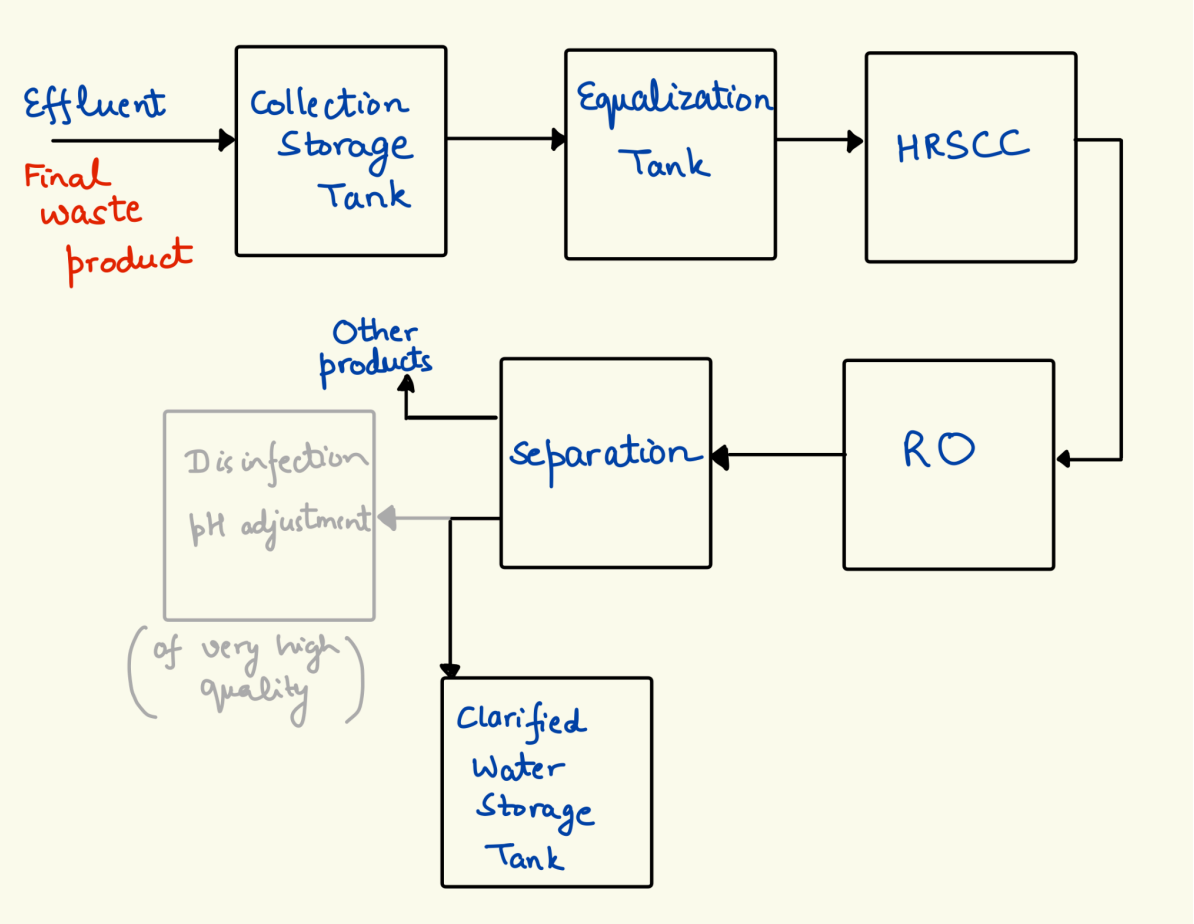
**Liquid wastes:** Waste Water, Ethanol, CMP, acrylic acid, methacrylic acid, MPEG (lower).
**Precaution:** Avoid mixing of Ethanol and CMP, because the boiling point difference is less than 20 ℃ (approximately 6 ℃).
**Important:**

1. Separate CMP from 202 (output stream of R101) through distillation of liquid (contains waste liquid: AA, MA, CMP).
2. MPEGs are liquid (lower).

**Boiling points:**

1. Wastewater ≅ 100 ℃
2. Ethanol ≅ 78.37 ℃
3. CMP ≅ 72℃
4. Acrylic acid ≅ 141 ℃
5. Methacrylic acid ≅ 161 ℃
6. MPEGs > 200 ℃

## ** TREATMENT OF WASTE EXCEPT CMP:




## 1. Collection

The first step involves collecting all liquid waste in a **storage tank**. Treating waste in individual steps could improve efficiency but would significantly increase installation costs, therefore preferring collecting all liquid waste together (except CMP).

## 2. Equalization

After collection, the waste is sent to an **equalization tank**, which plays a crucial role in stabilizing variations in flow rate, pH, and contaminant concentration. This helps in maintaining a consistent and uniform composition before further treatment.

This also helps in improving the efficiency of downstream processes.

## 3. High-Rate Solid Contact Clarification (HRSCC) and Reverse Osmosis (RO) (***Not Compulsory, can be skipped***)

- **HRSCC (High-Rate Solid Contact Clarification):**
  - Removes suspended solids, colloidal particles, and residual organic matter.
  - Uses coagulation and flocculation.

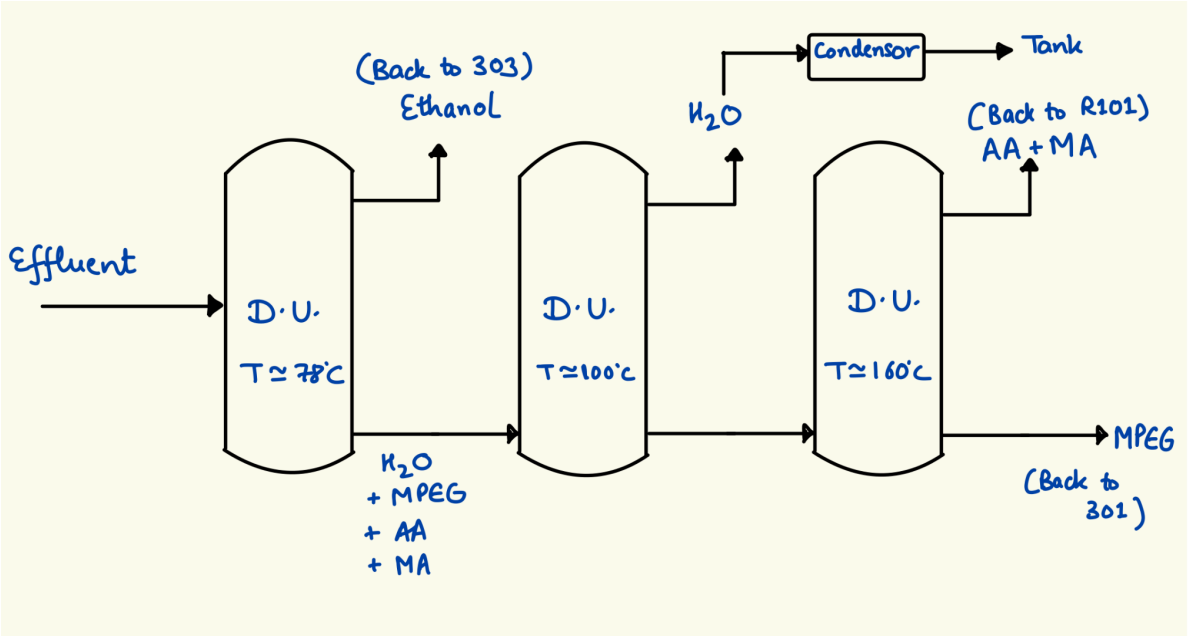
- **Reverse Osmosis (RO):**
  - Uses a semi-permeable membrane to remove fine particles.
  - Produces high-purity water.

This will help in removing dissolved $K_2CO_3$ in the liquid waste. These two processes can be skipped because distillation is already enough to make water and other wastes (except MPEG, which may need these two processes) pure enough to reuse.

## 4. Separation Process

The waste then undergoes a **separation process** in a distillation units (see figure below), which operates in multiple stages:

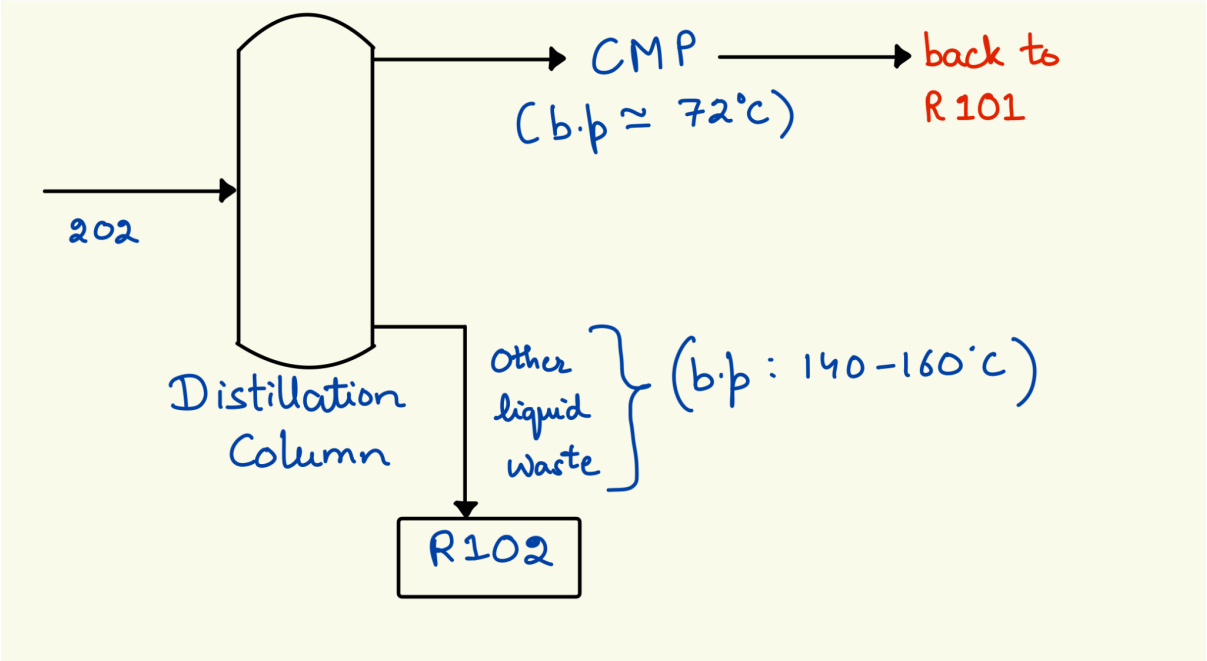
- **First distillation:** Ethanol, having the lowest boiling point, is distilled first and can be recovered for reuse in R102 through 303 stream.
- **Second distillation:** Water is distilled and condensed, then directed to the **Zero Liquid Discharge (ZLD) process**.
- **Third distillation:** Acrylic acid (AA) and methacrylic acid (MA), distilled, are sent back to R101.
- **MPEG Recovery:** MPEG remains as a liquid, back to 301.




## 5. Water Reuse and Zero Liquid Discharge (ZLD)

- After distillation, the purified water is of sufficient quality. It can be reused in cooling systems (or any other process) in **Heat exchangers** in the ZLD.
- If required, post-treatment methods like disinfection or pH adjustment can further enhance water quality for applications such as bathing or even drinking. However, due to higher costs, this additional treatment is not implemented in our process.

## ** TREATMENT OF CMP:




CMP is distilled from stream 202, as it has a lower boiling point compared to other products in 202 (AA and MA).

This significant difference in boiling point helps in separating very pure CMP, which can be sent back to R101, while the remaining liquid waste can be sent to R102, which will be at the end collected in the collection storage tank (mentioned above).

d. Are there any safety concerns for the chemicals? Give exposure limits: Time Weighted Average (TWA) for 8 hours and short-term exposure limit (STEL) for 15 minutes.

| **Chemical** | **TWA (8 hours)** | **STEL (15 minutes)** | **Safety Hazards** | **Precautions** |
|---|---|---|---|---|
| Ethanol | 1000 ppm (OSHA PEL, NIOSH REL) | 1000 ppm (ACGIH TLV-STEL) | Highly flammable in air. Inhalation causes dizziness, drowsiness, etc. Long-term exposure may affect the liver and nervous system | Keep away from heat sources. Store in tightly closed containers. |
| Methoxy Polyethylene Glycol | No mention | No mention | **Generally safe**<br><br>Skin and eye irritation only in high concentrations. Possible foaming in water sources. Can release **formaldehyde** at high temperatures. | Use gloves when handling concentrated solutions.<br><br>Store at room temperature away from oxidizers. |

| Chemical | TWA (8 hours) | STEL (15 minutes) | Safety Hazards | Precautions |
|---|---|---|---|---|
| Acrylic Acid | 2 ppm (NIOSH REL, ACGIH TLV-TWA)<br><br>OEL (Occupational Exposure Limit) **EU:** 10 ppm (29 mg/m$^3$) over an 8-hour TWA. | **DOSH:** 20 ppm (59 mg/m$^3$) averaged over a 15-minute period. [2] | Flammable, Corrosive on skin and eye, Inhalation Toxicity, Polymerization risk. | Store below 15 ° C.<br><br>Use PPE. Ensure ventilation. |
| Methacrylic Acid | 20 ppm (NIOSH REL, OSHA PEL, ACGIH TLV-TWA) | No mention. | Same as Acrylic acid. | Store in inhibited form (with hydroquinone).<br><br>Use PPE.<br><br>Keep away from heat and oxidizers. |
| 3-Chloro-2-methyl-1-propene | No mention | 0.3 mg/m$^3$ [4, only mention across all websites] | Flammable<br>Harmful if inhaled, swallowed, or absorbed through the skin.<br>Classified as a **Group 3 (IARC)** Carcinogen.<br>Toxic to aquatic life. | Use in a fume hood with PPE.<br>Store away from oxidizers in cold-dry areas. |

**References:** Provide reference for a material safety data sheet/industrial safety report/weblink.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28. https://www.osha.gov/ (used for each waste mentioned)
29. https://cpcb.nic.in/ (used for each waste mentioned)

**List the contributions of each author:**

**Arsh Jaswal :**

1. Analysed current regulations for the waste materials ( ethanol solvent, methoxy polyethylene glycol, acrylic acid )
2. Treatment procedure for wastes with main flow chart, main idea and process detail.
3. Exposure limits data with TWA and STEL.

**Amish Verma** :

1. Analysed current regulations for the waste materials ( methacrylic acid, 3-chloro-2-methyl-1-propene, potassium carbonate ) and wrote the COD and BOD limit details.
2. Safety concerns and precautions for the wastes.

**Om Singh**:

1. Handled all material balance calculations and determined the total waste generated Quantity.
2. Worked on CMP (Chemical Manufacturing Process), its flowchart, process details and Treatment of CMP.

**Yash Upadhyay**:

1. Contributed to the separation process, developed the flowchart, and provided boiling points of relevant substances.
2. Analyzed the flow sheet and described the waste output stream.

# CHE261A Environmental Clearance

Sign the pdf and upload.

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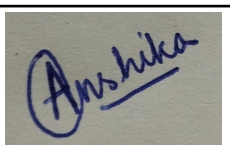
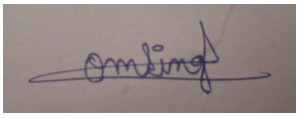
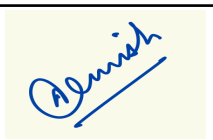
|---|---|---|
| Anshika Agrawal | 230160 |  |
| Om Singh | 230720 |  |
| Yash Upadhyay | 231189 |  |
| Arsh Jaswal | 230205 |  |
| Amish Verma | 230121 |  |