**Applicant:** GreenovateX

**Inventors:** Aman Singh

**Chemical Product Formula:** C₁₀H₁₉O₆PS₂

**Chemical Product Name:** Malathion

**EHS Summary:**

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

**Basis of Calculation**

* **Reference Batch Size**: 1,000 kg of Malathion (final product)
* **Yield Assumptions**:
  + Direct Esterification: 98% yield (industry standard for optimized processes)
  + Thio phosphorylation: 93% yield (due to side reactions)

1. **Direct Esterification Route:**
2. **Aqueous Waste (Neutralization):**

* **Source**: Water (byproduct) + NaOH/H₂SO₄ neutralization
* 1 mol Malathion → 1 mol H₂O (byproduct)
* Molar mass Malathion = 330.4 g/mol → 1,000 kg ≈ 3,026 mol
* **H₂O generated** = 3,026 mol × 18 g/mol = **54.5 kg**
* Assume 5% excess H₂SO₄ → Neutralized with NaOH → Na₂SO₄
* Estimated salt waste: **200 kg** (empirical, based on acid-catalyst load)
* **Total Aqueous Waste**: 54.5 kg (H₂O) + 200 kg (salts) ≈ **250–300 kg**

1. **Solvent Residues (Toluene/Xylene):**

* **Assumption**: 10% solvent loss in distillation (industry norm)
* Mentioned that toluene/xylene as carrier solvents (~500 kg/batch)
* **Waste solvent** = 10% of 500 kg = **50 kg**

#### **Filtration Residues (Unreacted Solids):**

* **Source**: Unreacted DEM/DMPA (2% of inputs, per 98% yield)
* **Unreacted DEM**: 2% of 518 kg (DEM input) = **10.4 kg**
* **Unreacted DMPA**: 2% of 482 kg = **9.6 kg**
* **Total solids**: 10.4 + 9.6 ≈ **20 kg**

#### **Neutralization Salts:**

* **Source**: Neutralization of sulfuric acid (H2​SO4) or p-TSA with NaOH/Na₂CO₃
* **Catalyst Load**: 5% H2​SO4​ by mass of DMPA
  + DMPA required for 1,000 kg Malathion (98% yield):

DMPA =

* + H2​SO4​ used: 5% of 482 kg = **24.1 kg**
* **NaOH for Neutralization**:
  + 1 kg H2​SO4​ requires 0.816 kg NaOH → **19.7 kg NaOH**
  + Salt (Na2​SO4​) formed:

Na2​SO4 =

1. **Thio phosphorylation Route**
2. **H₂S Gas:**



* **Molar Masses**: P₂S₅ = 222 g/mol, H₂S = 34 g/mol
* **H₂S per kg P₂S₅**:
* **P₂S₅ Required**:
  + For 1,000 kg Malathion (93% yield):

DMPA needed = P2​S5 ​needed

* + **H₂S Generated**: 360 kg P2S5 × 0.306 = 110 kg
* **Scrubbing Efficiency**: ~70% captured → **33 kg released** (estimate: **50–80 kg**)

#### **Solvent Waste (Hexane/DCM):**

* **Solvent Input**: ~500 kg/batch (for extraction)
* **Losses**:
  + 10% adhesion to equipment
  + 5% dissolved in aqueous phase
  + Total loss: **15% of 500 kg = 75 kg** (range: **70–120 kg**)

#### **Methanol Residues (40–60 kg):**

* **Source**: Excess methanol in P₂S₅ reaction
* 4 mol CH₃OH per mol P₂S₅
* **Excess Methanol**: 20% excess → **42 kg unreacted**
* **Distillation Losses**: 5% → **10 kg**
* **Total**: **40–60 kg**

#### **Acidic/Basic Waste:**

* **Source**: Neutralization of residual acids (H₂SO₄) or bases (NaOH)
* **Assumptions**:
  + 5% excess H₂SO₄ used in Thio phosphorylation (similar to esterification)
  + Neutralization with NaOH → Na₂SO₄
* **H₂SO₄ Load**: 5% of DMPA mass = 0.05 × 507 kg = **25.4 kg**
* **Na₂SO₄ Formed**:
* **Aqueous Waste**: Includes water from reaction (~50 kg) + washings → **200–400 kg** (empirical for industrial scales)

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

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| --- | --- | --- | --- | --- |
| ****Waste Type**** | ****Composition**** | ****Regulatory Limit**** | ****CPCB Rule Reference**** | ****Disposal Method**** |
| **H₂S Gas** | Hydrogen sulfide | ≤ 5 mg/Nm³ (emission limit) | HW Rules  HW35 | Scrubbing with NaOH → Convert to Na₂S |
| **Acidic/Basic Waste** | Na₂SO₄/NaCl/  H2SO4 | - pH 6.5–8.5 - TDS ≤ 2,100 mg/L - Sulfates ≤ 1,000 mg/L | HW34 (Corrosive waste (pH <2 or >12.5)) | Neutralization → Discharge to CETP or evaporation pond |
| **Solvent Waste** | Hexane/DCM  /Toluene | - VOC ≤ 150 mg/Nm³ - Halogenated solvents (DCM) require incineration | HW40 (DCM) HW41 (Hexane/Toluene) | Incinerate (≥99.9% destruction) or recover via distillation |
| **Solid Residues** | P₂S₅ sludge, filter aids | -Reactive sulfides <1% -Leachate TCLP: Pb/Cd/As <5 mg/L | HW29 (Reactive sulphur compounds) | Stabilization with lime → Landfill in secured hazardous waste facilities |
| **Filtration Residues** | Unreacted DEM/DMPA | -Landfill: TOC <3% for non-hazardous waste -Incineration: ≥99.9% destruction efficiency | HW08 (Organic residues) | Incineration or secure landfill after stabilization |
| **Methanol Residues** | | ≤ 250 mg/L (discharge limit) | HW10 (Ignitable waste (flash point <60°C)) | Incineration with energy recovery or reuse |

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

A diagram of a process flow

AI-generated content may be incorrect.

1. 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.

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| ****Chemical**** | ****Safety Concerns**** | ****TWA (8-hr)**** (ACGIH) | ****STEL (15-min)****  (ACGIH) | ****Safety Measures**** |
| ****Malathion**** | Eye Irritation, Fatal Poisoning, Nausea, Loss of Coordination | **10 mg/m³** | **10 mg/m³** | PPE: Gloves, respirator (APF 10), Avoid inhalation |
| ****DMPA**** | Flammable, Toxic Swallowed or Inhaled, Severe Skin & Eye Damage, Reproductive Toxicity | **NA** | **NA** | Acid-resistant PPE, Fume hood handling |
| ****DEM**** | Skin sensitization, Eye irritation | **NA** | **NA** | Respirator, Ventilation, Protective Gear, PPE, Avoid Contact |
| ****P₂S₅**** | Flammable, Toxic if Inhaled, Skin and Eye Irritation, Reacts with Water, Releases Toxic Gas | **1 mg/m3** | **3 mg/m³** | Wear PPE, Use Respirator, Avoid Water Contact, Ensure Ventilation, Store in Dry Area |
| ****H₂S**** | Toxic, Flammable, Causes Respiratory Issues | **1 ppm** | **5 ppm** | Use respirator, ensure ventilation, avoid confined spaces |
| ****H₂SO₄**** | Corrosive, Causes Severe Burns, Reacts Violently with Water | **1 mg/m³** | **3 mg/m³** | Wear PPE, handle with care, add acid to water slowly |
| ****CH₃OH**** | Flammable, Toxic if Ingested, Causes Blindness | **260 mg/m³** | **325 mg/m³** | Use in ventilated area, avoid ingestion, store away from flames |
| ****C₇H₈**** | Flammable, Harmful Vapours, Affects Nervous System | **375 mg/m³** | **560 mg/m³** | Wear gloves, use in fume hood, keep away from heat |
| ****DCM**** | Toxic Vapours, Carcinogenic, Harmful to Skin and Eyes | **25 ppm** (OSHA) | **125 ppm** (OSHA) | Use fume hood, wear protective gear, avoid skin contact |

**References:** Provide reference for a material safety data sheet/industrial safety report/weblink.

* <https://students.aiu.edu/submissions/profiles/resources/onlineBook/z5y2E6_Perry-s_Chemical_Engineers-_Handbook.pdf>
* <https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors-stationary-sources>
* <https://cpcb.nic.in/rules/>
* <https://p2infohouse.org/ref/33/32302.pdf>
* <https://www.acgih.org/science/tlv-bei-guidelines/tlv-chemical-substances-introduction/>
* <https://www.osha.gov/chemical-hazards/standards>
* <https://www.niehs.nih.gov/>
* <https://www.nj.gov/>

**List the contributions of each author: Aman Singh**

* Determined the waste generation quantity.
* Carried out the literature search and found the current regulations.
* Found necessary treatment steps and prepared the block diagram.
* Obtained TWA and STEL data.

**Sign the pdf and upload.**

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| Name | Roll No | Signature |
| CEO Name |  |  |
| Aman Singh | 200105 | A close-up of a signature  AI-generated content may be incorrect. |