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Chemical Product Formula: C₈H₉NO₂

Chemical Product Name: Acetaminophen(Paracetamol)

Process Title: Integrated Process for the Production and Purification of Paracetamol from Nitrobenzene

EHS Summary:

- a. List the wastes generated and their quantity of generation.
- b. What the current regulations for the above waste materials. (Limits to which it can be disposed in the environment)
- c. Describe the treatment procedure for wastes with block diagram. Your chemical plant must be a zero liquid discharge plant.
- 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.

Waste Generation in Paracetamol Production

In the production of paracetamol (also known as acetaminophen), several waste materials are generated. Here's a concise list:

1. Crude Aqueous Reaction Mixture:
 - Formed during the synthesis process.
 - Contains **p-aminophenol** and other byproducts like **aniline and acetic acid**.
 - **Aniline waste**=318.12 kg/day.
 - **Acetic acid with acetic anhydride waste** = 2106.00 kg/day.

ite Containing Acetic Acid and Dissolved Paracetamol:

- Filtrate obtained after recovering paracetamol by filtration.
- **acetic acid dissolved in paracetamol** = 1004.82 kg

- Contains acetic acid and dissolved paracetamol.

3. Excess Filtrate:

- Filtrate not used for paracetamol synthesis.
- Stored in a storage tank for subsequent distillation.
- **on excess filter quantity** = 84.34 kg

4. Distilled Residue:

- Obtained after distillation of excess filtrate.
- Contains acetic acid and other impurities.
- **Quantity**: 84.34 kg

Current Regulations for Waste Disposal

Regulations regarding waste disposal vary by region and country. However, common guidelines include limits on the release of hazardous substances into the environment. For paracetamol production waste, the following aspects are regulated:

1. Discharge Limits:

- Limits on the concentration of specific chemicals (e.g., acetic acid) in effluents.
- Compliance with local environmental standards.

2. Zero Liquid Discharge (ZLD):

- Some regions require ZLD units to minimise liquid effluents.
- ZLD aims to **recover water** and **concentrate waste** for disposal.

Treatment Procedure in a Zero Liquid Discharge Plant

Here's a block diagram illustrating the treatment procedure in a ZLD chemical plant for paracetamol production:

1. Waste Collection and Segregation:

- Collect waste streams of aniline and acetic acid separately.

Segregate hazardous and non-hazardous waste.

2. Pretreatment:

- Neutralization, coagulation, and flocculation.
- Screening and filtration to remove solids.

3. Evaporation:

- Multiple Effect Evaporators (MEE) or Mechanical Vapour Compression (MVC).
- Recover water and concentrate brine (waste).

4. Crystallization:

- Further concentrate brine.
- Harvest crystallized salts (e.g., NaCl).

5. Solid Waste Management:

- Filter presses or centrifuges for dewatering sludge.
- Incinerate organic solids.
- Dispose of ash safely.

6. Water Recovery:

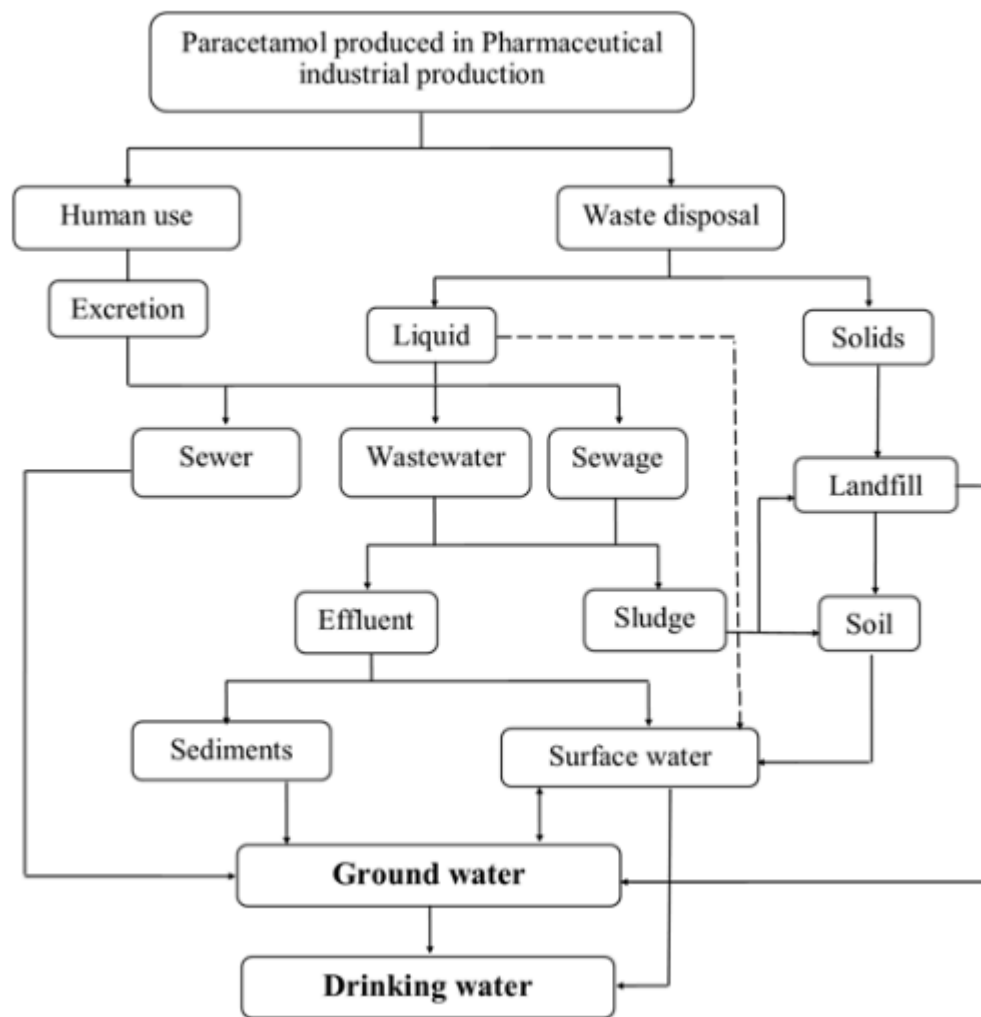
- Reverse osmosis (RO) to treat remaining brine.
- Recover purified water for reuse.

7. Final Disposal:

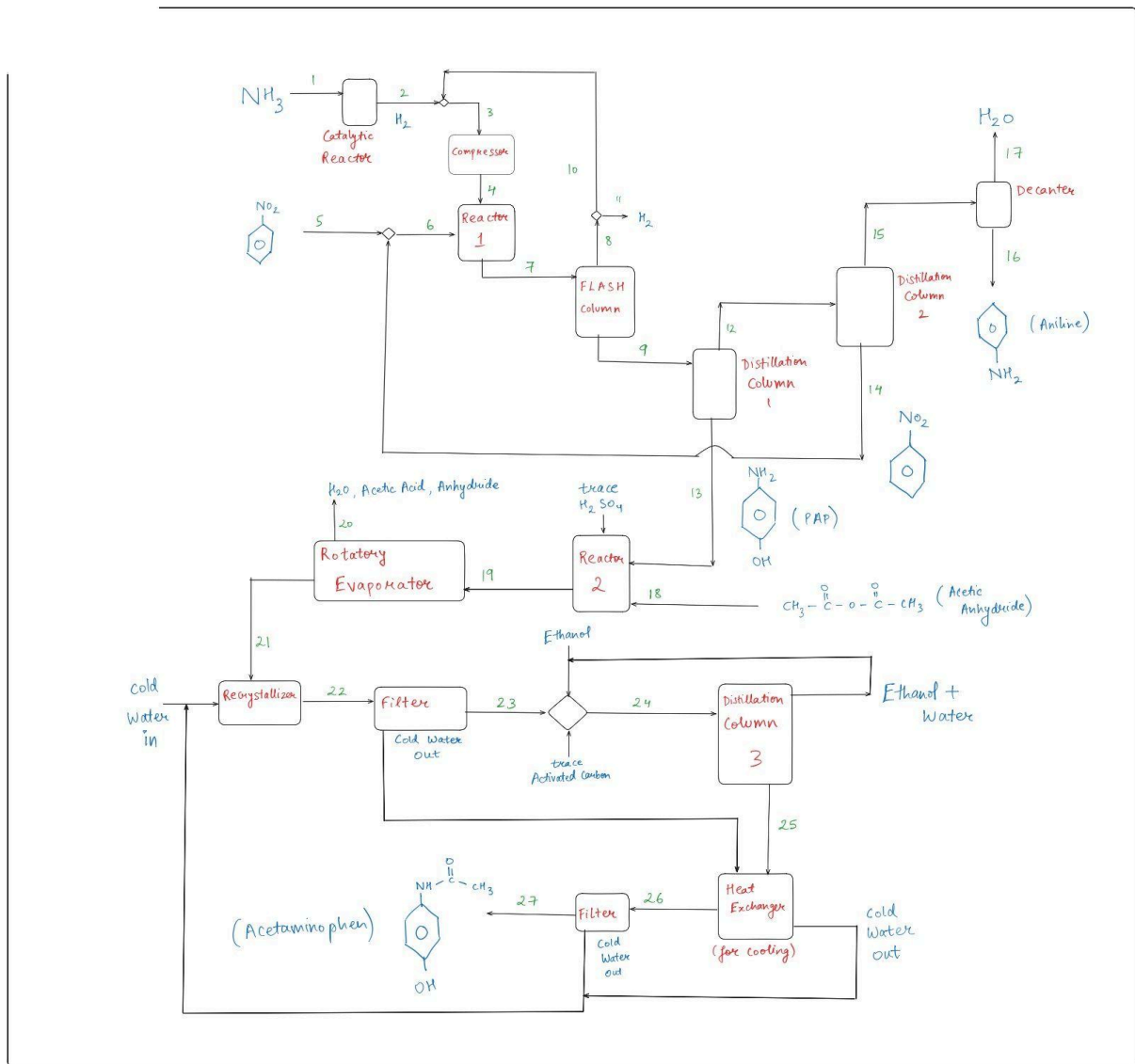
- Landfill for solid waste.
- Salt ponds for concentrated brine.

Pathway of Paracetamol to aquatic environment:

The pharmaceutical industry holds a major role in polluting water resources. Paracetamol substance is constantly introduced into the aquatic environment by several discharges from manufacturing facilities, consumer use and disposal, and hospital waste.



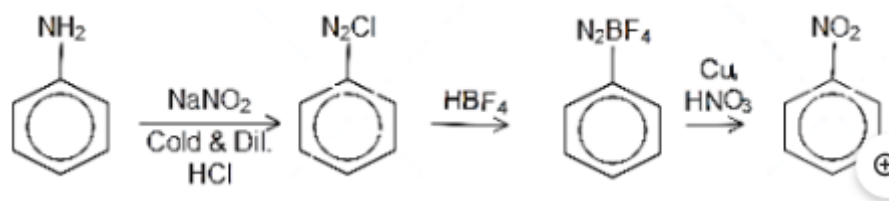
Bulk paracetamol production generates high strength wastewaters that have **COD values of around 20000 mg/L**.



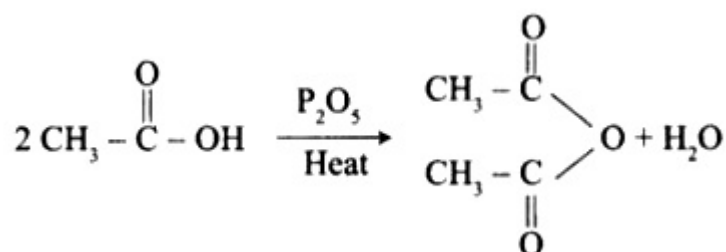
Here we can also use the byproduct which we get from this process.

Use of Byproduct:

Aniline : Aniline can be treated with a cold dilute acidic solution sodium nitrite in the temperature range of (0 - 5) degree celsius to form diazo compounds which form the intermediate for the transformation reaction. This is then treated with hydrogen fluoroborate or HBF_4 to form the fluoro salt of the diazo compound. Then this salt is treated with copper and sodium nitrite to form nitrobenzene.



Acetic acid: we can use acetic acid by converting it to acetic anhydride. Acetic anhydride can be made from acetic acid (CH_3COOH) by treating it with phosphorus pentachloride (PCl_5) or dicyclohexylcarbodiimide (DCC). With PCl_5 , the reaction is a two step process. First, CH_3COOH is converted into the acyl chloride ($\text{CH}_3\text{CO-Cl}$) and then reacts with acetic acid.



Safety Concerns for Chemicals

1. Paracetamol (Acetaminophen):

- Generally well-tolerated.
- Risk of liver toxicity with high doses (>4 g/day).
- Regular large doses can lead to serious side effects.

2. Nitrobenzene: Nitrobenzene needs to be kept away from the hot surface. It will be flammable if the temperature goes above the flash temperature (88 degree celsius). It must be stored in a dry and well ventilated closed container. Avoid contact with the skin and eyes and inhalation of the vapour. The area must be a non-smoking zone to prevent any hazard to the plant. Flame can be extinguished using cold water or dry carbon dioxide

3. Hydrogen: Hydrogen is a non-toxic gas. The important precaution is to be kept in a sealed container to avoid any leakages. Leakage may lead to the formation of the flammable mixture with air. Leakage can be due to process failure, container material or not proper maintenance.

4. Aniline: Aniline is a flammable substance and not safe for disposal in water bodies. Heating of the chemical produces very harmful chemical vapours. Must be stored in the ventilated rooms in steel tanks. Storing temperature must be around 25-30 degree celsius.

5. Para-aminophenol: Para- AmnioPhenol needs to be carefully used, exposure to the chemical will lead to irritation in the skin and eyes, and may also lead to asthma. Hence, the people operating need to wear protective clothing. The storage container needs to be kept away from the heat source.

6. Acetic Acid: Acetic acid is a flammable liquid and vapour. It can be a hazardous chemical if not used in a safe and appropriate manner. This liquid is highly corrosive to the skin and eyes and, because of this, must be handled with extreme care. Acetic acid can also be damaging to the internal organs and nose, throat if ingested or in the case of vapour inhalation. The use of PPE (personal protective equipment) is essential when handling this chemical in an undiluted state.

7. Acetic Anhydride: Acetic Anhydride is corrosive to eye, skin and respiratory system. Inhalation may cause lung oedema, but only after initial corrosive effects on eyes and/or airways have become manifest. A harmful contamination of the air can be reached rather quickly on evaporation of this substance at 20°C.

TWA and STEL data

Annotations

Carc: Capable of causing cancer and/or heritable genetic damage.

Sen: Capable of causing occupational asthma.

Sk: Can be absorbed through the skin. The assigned substances are those for which there are concerns that dermal absorption will lead to systemic toxicity.

	CAS number	Workplace exposure limit				Comments
		Long-term exposure limit (8-hr TWA reference period)		Short-term exposure limit (15-minute reference period)		
		ppm	mg.m ⁻³	ppm	mg.m ⁻³	The Carc, Sen and Sk notations are not exhaustive. Notations have been applied to substances identified in IOELV Directives
Paracetamol,inhalable dust	103-90-2	-	10	-	-	
Nitrobenzene	98-95-3	0.2	1	-	2.6	Sk
Hydrogen	-		-	-	-	
Aniline	62-53-3	1	4	-	20	
Para-aminophenol	95-53-4	0.2	0.89	-	-	Carc , Sk
Acetic Acid	64-19-7	10	25	20	50	
Acetic Anhydride	108-24-7	0.5	2.5	2	10	

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

- 1) https://www.ilo.org/dyn/icsc/showcard.display?p_version=2&p_card_id=0363&p_lang=en#:~:text=The%20substance%20is%20corrosive%20to,or%20airways%20have%20

[ecome%20manifest.&text=A%20harmful%20contamination%20of%20the,substance%20at%2020%C2%B0C.](https://www.ilo.org/dyn/icsc/showcard.display?p_version=2&p_card_id=0363&p_lang=en#:~:text=The%20substance%20is%20corrosive%20to,or%20airways%20have%20)

- 2) by international safety cards
https://training.itcilo.org/actrav_cdrom2/en/osh/ic/108247.htm
- 3) <https://ehs.princeton.edu/about-ehs>
- 4) <https://www.scientiaricerca.com/srcops/SRCOPS-01-00033.php> effect of paracetamol on environment.
- 5) <https://pubmed.ncbi.nlm.nih.gov/8490583/> use of byproduct.

List the contributions of each author:

- (Example) Author 1 determined the waste generation quantity.
- Author 1 and 2 carried out the literature search and found the current regulations.
- Authors 1, 2 and 3 found necessary treatment steps and prepared the block diagram.
- Author 4 obtained TWA and STEL data.

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