Applicant: National Chemicals Limited (NCL)

CEO: Sidhant Thalor (221055)

Inventors: Punam Singh (220835)

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Chemical Product Formula: $C_{13}H_{19}Br2ClN2O$

Chemical Product Name: Trans-4-(2-amino-3,5-dibro-benzylamino)-cyclohexanol

Common Name: Ambroxol Hydrochloride (Ambroxol)

Process Title: Removal of effluents during the production of Ambroxol

EHS Summary:

a. **Wastes generated and their quantity of generation**

Inorganic Borate Salt - 499 kg per 455 kg Sodium Borohydride
Spent Carbon - 28 kg per 2340 kg Methanol

b. **Current regulations for the above waste materials. (Limits to which it can be disposed in the environment)**

Borate Compounds are on the Right to Know Hazardous Substance List because they are cited by The American Conference of Governmental Industrial Hygienist (ACGIH) and The National Institute for Occupational Safety and Health (NIOSH).

- Boron concentrations in drinking water are set below **0.5 mg/L** by the World Health Organization.
- Japanese effluent standards stipulate that the concentration of Boron in wastewater should be **below 10 mg/L**.

Spent carbon (Carbon Residue) is categorised as hazardous waste under S.No 18.2 of schedule-I of HOWM Rules, 2016, which must be disposed of in an authorised disposal facility per authorization conditions when not utilised in manufacturing Carbon black. This chemical is considered hazardous by the United States 2012 OSHA HazardCommunication Standard.

- Spent carbon is not explicitly addressed in EPA regulations. If spent carbon is reclaimed (e.g., for regeneration or reuse), it is not considered solid waste.

c. Treatment procedure for wastes with block diagram

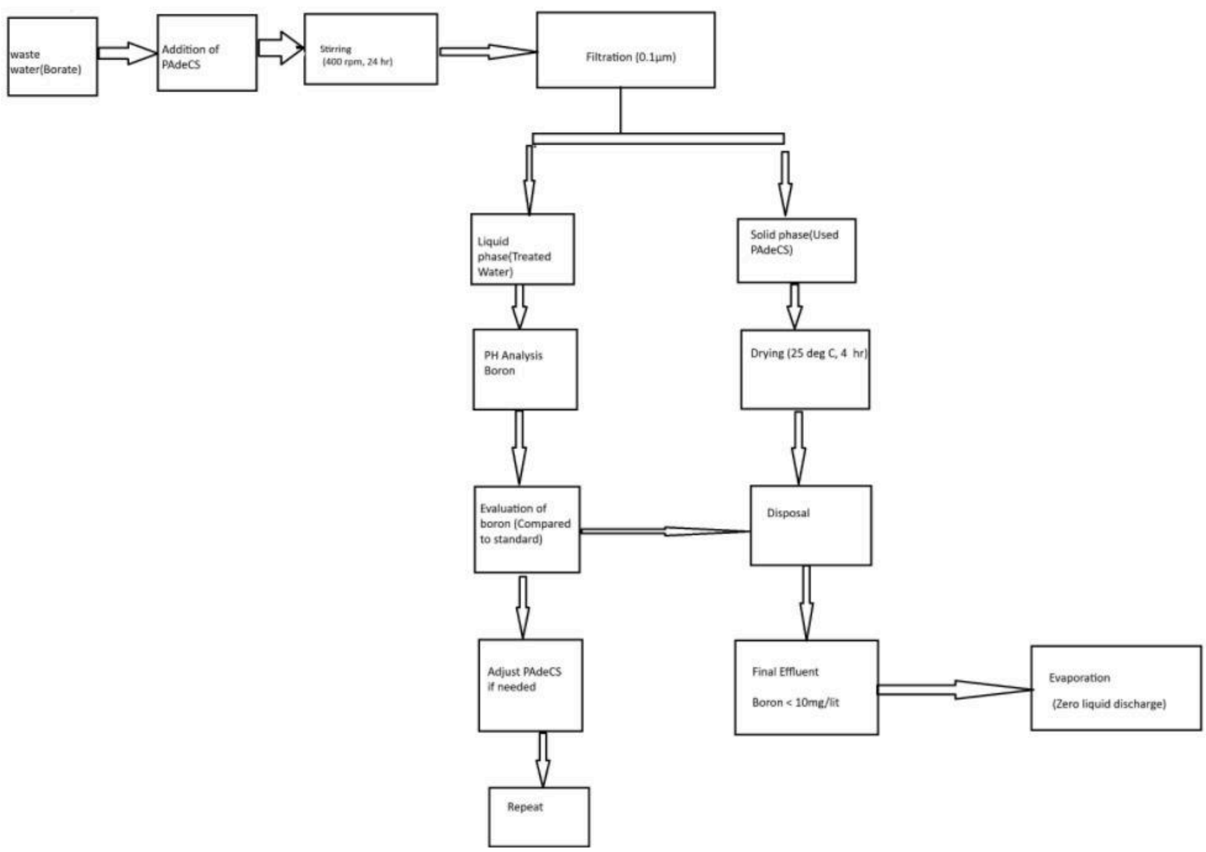
1. Treatment of **Inorganic Borate Salt** from wastewater using **Adsorbent**:

- We will remove borate ions(that are output from sodium borohydride in step 2 of the process) from wastewater using adsorbent prepared from waste concrete (PAdeCS - phosphorous adsorbent derived from Concrete Sludge) and treatment of waste sludge after removal.
- The coagulation method with PAdeCS for ettringite preparation in the solution shows the highest performance of boron removal, where boron concentration decreased from 100 mg/L to the level below the Japanese effluent standard at 10 mg/L.
- The weight ratio of PAdeCS addition into water is 4% with aluminium sulphate, of which the added amount corresponds to the stoichiometric condition for the formation of ettringite(Ca6Al2(SO4)3(OH)12·26H2O)
- How is PAdeCS obtained - It is obtained by filtration of freshwater concrete after adding excess water to prevent hardening. The main component of PAdeCS is hydrated cement, which is strongly alkaline and rich in calcium (~28.9 wt%). It also contains a small amount of ettringite, known for having an ion exchange ability by replacing sulphate ions with other anions.
- Untreated PAdeCS and aluminium sulfate, a source of aluminium and sulfate, will be mixed in the model wastewater. The mass fraction of PAdeCS is changed in the 2.0-8.0% range, and that of aluminium sulfate is fixed at 0.82%. The stoichiometric condition for ettringite corresponds to the mass ratio of PAdeCS at 2%.
- The mixture is stirred with a magnetic stirrer at 400 rpm for 24 hours. The liquid phase is then sampled through filtration, the boron concentration is measured and the pH of the mixture is measured with a pH meter. After 24 hr, the mixture is vacuum-filtered using a nitrocellulose filter(pore size: 0.1 micrometres), and the solid residue is dried at 25 degrees Celsius for 24 hr.
- The boron concentration after 24 hr is 0.41 mg/L for the case with a 5.0% dose. The Japanese effluent standard can be achieved within 1 hour for the cases with a dose higher than 4%.
- Then, to achieve a **Zero Liquid Discharge System,** wastewater is processed using membrane technologies such as electrodialysis and reverse osmosis. It involves pre-treatment, evaporation, and crystallisation.

- The pH remains almost unchanged, but higher doses of PAdeCS, the major calcium hydroxide component, resulted in a higher pH. The table below summarises the boron removal performance.

mass ratio of PAdeCS added (%)	initial concentration (mg/L)	concentration after 24 h(mg/L)	removal ratio (%)
2.0	100.7	41.01	59.3
3.0	103.3	5.46	94.7
4.0	103.8	2.13	97.9
5.0	104.0	0.41	99.6
6.0	103.8	0.48	99.5
8.0	102.7	1.2	98.8

Block Diagram of Boron Compound Treatment:



2. Treatment of **Spent Carbon** by **Thermal Reactivation**:

- Spent Carbon (GAC) can be recycled through thermal reactivation. This process involves passing the spent carbon through a high-temperature furnace at or above 850°C. The reactivation process consists of four steps:
- **Drying**: The spent carbon is fed into the furnace and heated to 105 – 110°C. This step removes water and low-boiling compounds released into the furnace atmosphere. The temperature of the carbon remains between 105 and 110°C as long as there is still water in the pores.
- **Desorption**: As the carbon dries, the temperature increases to around 450°C. Various organic compounds desorb from the carbon and escape into the furnace atmosphere.
- **Pyrolysis**: The temperature is further raised to about 600°C, causing the remaining organics to decompose into smaller molecules that are released into the furnace atmosphere. A char residue is formed in the pore structure of the activated carbon.
- **Gasification**: The carbon is heated to temperatures over 850°C, and steam is injected to reform the pore structure. Steam at temperatures above 600°C oxidizes the carbon in an endothermic reaction, resulting in the following:

  Solid-gas reactions

  $C + H_2O \rightarrow CO + H_2$ Endothermic (1)

  $C + CO_2 \rightarrow 2\ CO$ Endothermic (2)

  $C + \frac{1}{2}\ O_2 \rightarrow CO$ Exothermic (3)

  $C + O_2 \rightarrow CO_2$ Exothermic (4)

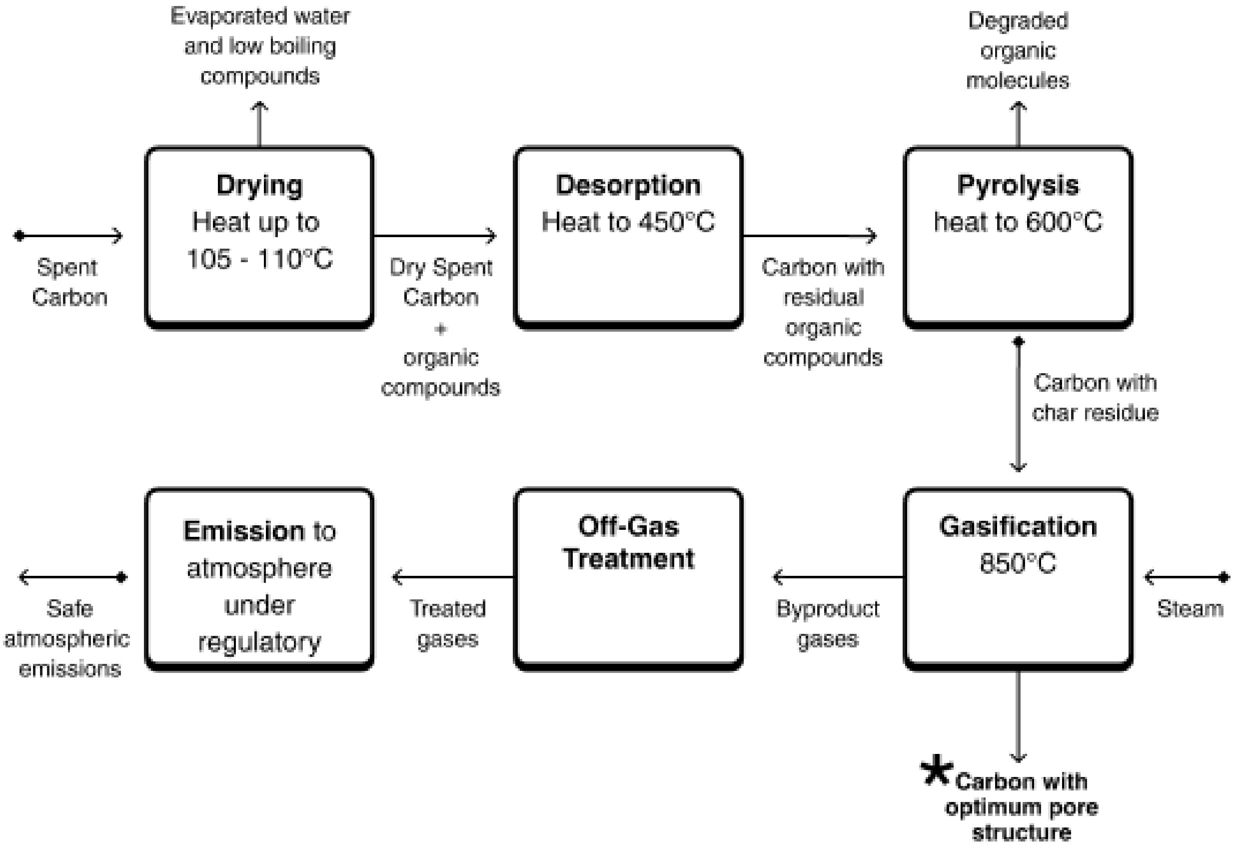
  Gas-gas reactions

  $CO + \frac{1}{2}\ O_2 \rightarrow CO_2$ Exothermic (5)

  $H_2 + \frac{1}{2}\ O_2 \rightarrow H_2O$ Exothermic (6)

- Since the solid-gas reaction (1) is three times faster than the solid-gas reaction (2), steam is injected into the furnace. The operating conditions of the furnace are adjusted to recover the pore structure to the optimum activation levels needed for the desired application.

Block Diagram of Spent Carbon Treatment:



d. Safety concerns for the chemicals. Exposure limits: Time Weighted Average (TWA) for 8 hours and short-term exposure limit (STEL) for 15 minutes.

Borate Compounds, Inorganic can affect when inhaled and by passing through the skin. Some of the safety hazards associated with it are:

- **Health Hazards**: Contact can irritate the skin and eyes, can cause nausea, vomiting, diarrhoea and may even affect the kidneys.
- **Fire and Explosion Hazards**: They are not combustible but may be strong oxidisers that enhance the combustion of other substances, and poisonous gases are produced in fire, including boron oxides.
- **Occupational Hazards**: Workers exposed to it in their workplace, such as in industries, are at risk of respiratory, skin, and eye problems, as well as other health problems.

Time Weighted Average (TWA) for 8 hours: The OSHA permissible exposure limit (PEL) for boron compounds is **2 mg/m3,** averaged over an 8-hour period.

Short-term Exposure Limit (STEL) for 15 minutes: The OSHA permissible short-term exposure limit for boron compounds is **6 mg/m3** over a 15-minute period.

Spent carbon, also known as exhausted carbon or used carbon, is a material resulting from depleting its adsorptive capacity by removing contaminants from air or liquids. The spent carbon may pose several safety hazards if not handled, stored, and disposed of properly. Here are some of the safety hazards associated with spent carbon:

- **Respiratory Issues:** Inhaling spent carbon dust can irritate the lungs, causing coughing, wheezing, and shortness of breath. Chronic exposure, especially to fine particles, can lead to lung diseases like fibrosis.
- **Skin and Eye Irritation:** Direct contact with spent carbon, particularly powdered forms, can irritate the skin and eyes, causing redness, itching, and discomfort.
- **Chemical Hazards:** Spent carbon in filtration applications might contain adsorbed toxins like heavy metals, solvents, or organic compounds. Inhalation or ingestion of these contaminants can lead to various health problems depending on the toxins involved.
- **Fire Hazard:** Although spent carbon is not flammable, it can pose fire hazards if it comes into contact with flammable materials or if it generates dust that can be combustible. Accumulation of dust from spent carbon should be managed carefully to mitigate the risk of fire.
- **Impact on Water Quality:** If spent carbon is disposed of in water bodies or if leachate from disposal sites contaminates water sources, it can impact water quality and aquatic ecosystems.

Time Weighted Average (TWA) for 8 hours: The permissible exposure limit (PEL) for Activated Carbon is **8 mg/m^3** averaged over an 8-hour period. (China)

Short-term Exposure Limit (STEL) for 15 minutes: The permissible short-term exposure limit for Activated Carbon is **10 mg/m3** over a 15-minute period. (China)

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List the contributions of each author:

- Punam and Vardaan determined the wastes and their generation quantity.
- Punam carried out the literature search, found the current regulations, found necessary treatment steps and prepared the block diagram for Inorganic Boron compounds.
- Vardaan researched the literature, found the current regulations, and necessary treatment steps, and prepared the block diagram for Spent Carbon.
- Vardaan and Punam obtained TWA and STEL data for spent carbon and inorganic boron compounds.

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