Environmental Technology Assessment

Training Scenario
Case Study – Polyethylene Production

Proposed Technology Investment

The purpose of this case study is to provide the basis for a practical, but fictitious application of EnTA. The case study is designed to provide relevant background information that, in conjunction with guidance from the Manual, can be used to complete the EnTA Worksheets. The focus of the present case study is Ana Plastics in Udanax City, Udanax. More details on Udanax can be found in the document that provides a description of that country.

Ana Plastics manufactures solid polyethylene particles, or "flake", from ethylene monomer. The manufacturing facility is located in the East Industrial Estate, some 20 km southeast of Udanax City and 10 km inland from the coast.

The central municipality of Udanax has recently made changes to the Water Pollution Regulations (1981). These set standards for the discharge of effluents. The new standards are being introduced over the next three years. In order to comply with these standards, Ana Plastics will have to either install a wastewater treatment system to treat the facility's wastewaters, or change the production process so that waste production is within acceptable limits.

In the current operation, as ethylene is polymerized the reactive mixture is scrubbed with dilute aqueous caustic solutions that become high volume pollutants in the wastewater stream. The discharge is sulphitic and, unlike pure caustic, non-recoverable. Ana Plastics propose to employ a neutralisation and steam stripping technology for the treatment of the spent caustic. However, there is considerable pressure from the community, and some professionals, for a change in the production process, rather than adopt an "end of pipe" solution.

The current task is to assess the environmental and related performances of the proposed technology intervention by reviewing, largely in a comparative manner, the environmental impacts of the proposed technology and two plausible alternatives.

Polyethylene Production

The two primary steps in the production of polyethylene are polymerization and extrusion. Ana Plastics operates a polymerization plant. The flake that is produced is delivered to various users who in turn manufacture diverse products.

In polymerization, ethylene monomer is transformed into solid polyethylene particles, consisting of long polymer chains. The material is similar in size and appearance to laundry detergent particles. Catalysts are critical to the polymerization process, which cannot proceed in their absence. Most commonly, highly active metallic catalysts are used. Before the late 1970s an organic peroxide catalyst was used, but due to it being less active, pressures in the reaction chamber had to be more than 100 times those now required as a result of using metallic catalysts.

All polyethylene is produced in one of four types of reactors: high pressure, solution, gas phase and slurry. Each process, along with specific catalyst groups and other additives, produces polyethylenes with certain performance advantages.

Wastewater Treatment

Increasing awareness of the potentially harmful effects of hazardous organic substances present in many industrial waste streams, such as spent caustic, has generated interest in establishing effective treatment technologies for these wastes (Stephenson and Blackburn Jnr., 1998). Several technologies are available for the treatment of spent sulphitic caustic; treatment methods include neutralisation with steam stripping, wet air oxidation (low, medium and high pressure) with neutralisation, and incineration (Stephenson and Blackburn Jnr., 1998). In addition, there are emerging technologies such as catalytic wet air oxidation and supercritical water oxidation.

Ana Plastics are proposing to treat the liquid waste stream, containing the spent caustic, by acid neutralisation followed by steam stripping. After neutralisation, stripping removes residual hydrogen sulphide and mercaptans. Neutralisation and steam stripping result in liberation of the acid gas (CO_2 and H_2S) which requires venting to an acid gas flare or routing to a sulphur recovery plant. In addition, the acidification process accelerates formation of oily polymer by-products which result in fouling and other operating problems. The residual mercaptans and sulphides in the treated caustic generate odours that may be noticeable even when diluted with other plant wastes. The liquid effluent exhibits high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) concentrations because the major portion of organic constituents are unaffected by the stripping process.

Spent caustic from a waste storage tank is pumped to a neutralisation system where the pH is adjusted. To convert sodium sulphide to hydrogen sulphide for subsequent stripping, the maximum acceptable pH of the influent to a steam stripper is 6.0. The effluent from the neutralisation process is injected with steam for temperature adjustment and then is pumped to the stripping tower. Typical operating conditions in the tower are 60 C and 0.2 barg. The overhead gases are either incinerated or sent to a sulphur recovery plant. The effluent is neutralised to a pH of about 7.0, cooled and then routed downstream to the plant’s process wastewater treatment system.

Fluidized Bed Polymerization Process

In the fluidized bed approach metallic catalyst particles are suspended (“fluidized”) in the ethylene fluid as the ethylene gas is pumped from the bottom of the reactor bed to the top. Before ethylene is sent to the fluidized bed it must first be compressed and heated. Pressures in the range of 100-300 PSI and a temperature of $100^{o}C$ are necessary for the reaction to proceed at a reasonable rate. The conversion of ethylene is low for a single pass through the reactor and it is necessary to recycle the unreacted ethylene. Unreacted ethylene gas is removed off the top of the reactor, where it is expanded and decompressed to separate the low molecular weight polymer from the gas. After purification, ethylene gas is recompressed and recycled back to the reactor. Granular polyethylene is gradually removed from the bottom of the reactor, as soon as reasonable conversions have been achieved. Typically a residence time of 3 to 5 hours results in a 97% conversion of ethylene.

An enormous amount of heat is liberated during the polymerization of ethylene as the reaction is exothermic. Heat is generally removed by cooling unreacted ethylene gas coming off the top of the reactor and recycling the cool gas back to the reactor.

With the use of a particularly active catalyst, the fluidized bed polymerization process can be made continuous and the use of scrubbing and solvents can be avoided. This means there are no water-based effluents. Hydrocarbon waste can be collected and incinerated.

Reference

Stephenson, R. L. and Blackburn, Jr. J.B. (1998). *The Industrial Wastewater Systems Handbook.* Lewis Publishers, New York.