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Environmental Impact of Barium Chloride Production Using LCA Method

Hao Liu[1,*], Qinghua Liang[2]

[1]*Beijing Degu Jiamei Environmental Technology Co., Ltd., Beijing, China*
[2]*Baotou Iron and Steel Vocational and Technical College, Baotou, Inner Mongolia, China*
degujiamei@163.com
[*]*Corresponding author*

Abstract: *Barium chloride is an important industrial raw material that can be used to produce other barium-containing compounds. This study focuses on a barium chloride production project at a chemical company, collecting and organizing data on materials and energy for different processes to obtain a lifecycle inventory for barium chloride production. A lifecycle impact assessment was conducted to clarify the environmental impacts of various process flows. The research confirms that industrial water usage is a significant environmental impact factor throughout the lifecycle of barium chloride production, followed by freshwater consumption and primary energy consumption. Within different production processes, coal consumption has a significant contribution to various indicators, followed by the consumption of concentrated mother liquor.*

Keywords: *Barium chloride; Lifecycle; LCA method; Normalization*

1. Introduction

With the advancement of science and technology, the production of high-purity barium chloride requires higher material standards and is widely used in aerospace, papermaking, and special steel industries. Industrial barium chloride is primarily produced using witherite as raw material. Witherite, a common barium-containing mineral, mainly consists of barium carbonate [1]. Studies show that witherite with mining value contains 60-70% barium carbonate. In the industrial production process, hydrochloric acid is used to leach witherite, converting barium to barium chloride. The barium chloride is then obtained through multiple filtration, crystallization, and other operations, which is a common process for producing industrial-grade barium chloride [2]. Barium chloride production demands high quality of minerals and energy, and can lead to environmental pollution. Lifecycle Assessment (LCA) involves quantitative analysis of material and energy usage, and environmental emissions to evaluate environmental issues caused by products or production processes. It further identifies and quantifies key opportunities to reduce environmental burden and proposes appropriate methods for environmental improvement. By applying LCA principles to the barium chloride production process, the study aims to provide recommendations for improving production processes, enhancing production efficiency, reducing energy consumption, and mitigating environmental pollution. The following sections collect lifecycle inventory data for barium chloride production and conduct a comprehensive lifecycle impact assessment to provide important references for the sustainable development of barium chloride production.

2. Research Methods and Inventory Collection

Lifecycle Assessment (LCA) originated in 1969 when the Mid-West Research Institute, commissioned by Coca-Cola, conducted a tracking and quantitative analysis of beverage containers from raw material extraction to final waste disposal. LCA is based on the standards outlined in ISO 14040 "Environmental Management — Lifecycle Assessment — Principles and Framework" [3]. The study focuses on traditional barium chloride production processes, including acidification, filtration, and centrifugal drying stages. LCA is a technique and method used to evaluate the environmental impacts of a product throughout its entire lifecycle, from raw material acquisition, production, to post-use disposal.To meet the requirements of lifecycle assessment, this study defines the functional unit as 1 ton. Input and output data were collected to obtain a complete lifecycle inventory, and eBalance software was

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used for comprehensive lifecycle impact assessment.

Inventory analysis is a crucial and time-consuming part of the LCA process, significantly affecting the accuracy of the final results. As an important iterative process, inventory analysis should revise system boundaries based on data collection. The system boundary includes barium chloride production processing and energy consumption but excludes raw material processing and transportation. Therefore, the production process of raw materials like hydrochloric acid is not considered. Barium chloride is produced from barium carbonate (BaCO3) through a reaction with hydrochloric acid. The process is as follows: barium carbonate powder is added to diluted hydrochloric acid and stirred to ensure full reaction. This reaction generates gas bubbles, and once complete, the pH is controlled to 2. Lime is then added to adjust the pH to 8. The solution is filtered and sent to the crystallization stage, and the clear liquid is transferred to the concentration evaporation section. Centrifugation and drying processes produce solid barium chloride. The production process primarily involves acidification, filtration, and drying stages, which are extensive and labor-intensive. The goal is to establish a lifecycle inventory for barium chloride production and collect relevant data from a barium chloride enterprise and related literature.

3. Lifecycle Impact Assessment of Barium Chloride Production

The lifecycle impact assessment for barium chloride production aims to comprehensively evaluate the impact factors of each production stage based on material consumption, pollutant emissions, and other information. Environmental evaluation indicators include: Inhalable Inorganic Substances (RI), Primary Energy Consumption (PED), and Acidification Potential (AP).

3.1 Characterization of Key Indicators

Characterization calculations are carried out using various quantification methods, which are mainly categorized into qualitative and quantitative types. Quantitative methods typically use equivalency factors to assess the environmental impact of various factors. Substances with similar environmental effects throughout the lifecycle can be converted and accumulated to corresponding reference values using equivalency factors (LCA characterization factors). The resulting value is known as the lifecycle characterization indicator for that effect type [4]. This process ensures that data within the same impact category are comparable, although comparisons between different impact categories cannot be made directly.

Using eBalance software, the characterization of environmental impacts for different stages of barium chloride production is presented in Table 1.

Table 1: Characterization Indicator Data for Barium Chloride Production

Indicator	Stage					
	Evaporation	Filtration	Centrifugation & Drying	Refinement	Packaging	Acidification
Acidification Potential (AP)	0	0	0	0	0	1.54E-03
Inhalable Inorganic Substances (RI)	0	0	5.57E-04	0	0	0
Abiotic Resource Depletion Potential (ADP)	2.50E-07	1.15E-09	1.11E-08	0	0	1.44E-07
Freshwater Consumption (WU)	4.54E+02	4.41E-01	2.77E+01	0	0	2.34E+02
Primary Energy Consumption (PED)	6.46E+00	2.99E-02	2.87E-01	0	0	3.72E+00
Chinese Fossil Energy Consumption Potential (CADP)	3.10E-01	1.44E-03	1.38E-02	0	0	1.78E-01
Industrial Water Usage (IWU)	4.54E+02	4.41E-01	2.77E+01	0	0	2.34E+02
Resource Depletion Potential in China (CADP)	3.10E-01	1.44E-03	1.38E-02	0	0	1.78E-01

The contribution rates of different stages to environmental impact types in the production process are shown in Figure 1.

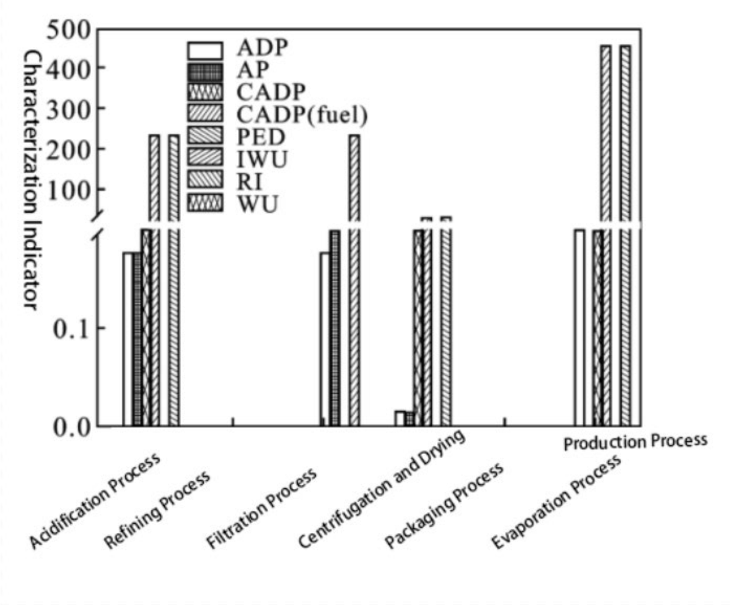

Figure 1: Contribution of Each Stage to Environmental Indicators in Barium Chloride Production

Analysis of Table 1 and Figure 1 reveals that the acidification and evaporation stages have significant impacts on industrial water consumption and freshwater usage. The centrifugation, filtration, and drying stages also affect water consumption but to a lesser extent compared to the acidification and evaporation stages.The high water consumption in the acidification stage is due to the large amount of fresh water used in the hydrochloric acid treatment, which leads to the formation of barium chloride solution or the discharge of waste liquids. To achieve green development and conserve water resources, future improvements could include optimizing the ratio between barite quality and hydrochloric acid to enhance reaction efficiency, thus reducing the need for fresh water. In the evaporation stage, significant freshwater is used for condensation. To address this, implementing a recycling pool to recover and reuse the condensed water would be beneficial.

The evaporation and filtration stages also impact primary energy consumption. The analysis shows that these processes consume electricity, which is generated from coal combustion. To reduce the environmental impact of primary energy consumption, alternative energy sources, such as solar power, could be explored. Although the acidification and centrifugation-drying stages have some impact on energy consumption potential, their effects are relatively minor. Additionally, the acidification stage affects the acidification potential due to the use of hydrochloric acid and barium carbonate powder, which leads to a reaction pH in the 4-5 range [5]. Therefore, future practices should include appropriate processes to treat acidic waste liquids in an environmentally friendly and non-polluting manner.

3.2 Normalization

Normalization is a dimensionless method that facilitates the comparison of various indicators, as shown in Figure 2. The purpose of normalization is to remove the unit of measurement from the product or system characteristics, allowing for the identification of the primary environmental impact factors of a product or system. In this study, the "CN-2010" standardization scheme [6] was selected and integrated into the eBalance software to determine the normalized indicators for different types of environmental impacts in the barium chloride production process.The research results indicate that industrial water consumption (EIWU) is the primary environmental impact factor in barium chloride production. Due to the large amount of fresh water required in various stages of barium chloride production, industrial water usage remains high, making it a major environmental concern. Improving the process by optimizing the ratio between hydrochloric acid and barium carbonate in the production of barium chloride could help reduce industrial water consumption and achieve higher levels of clean production. The normalization results suggest that future barium chloride production should focus on reducing water and primary energy consumption to ensure that clean production becomes a key aspect of evaluation.

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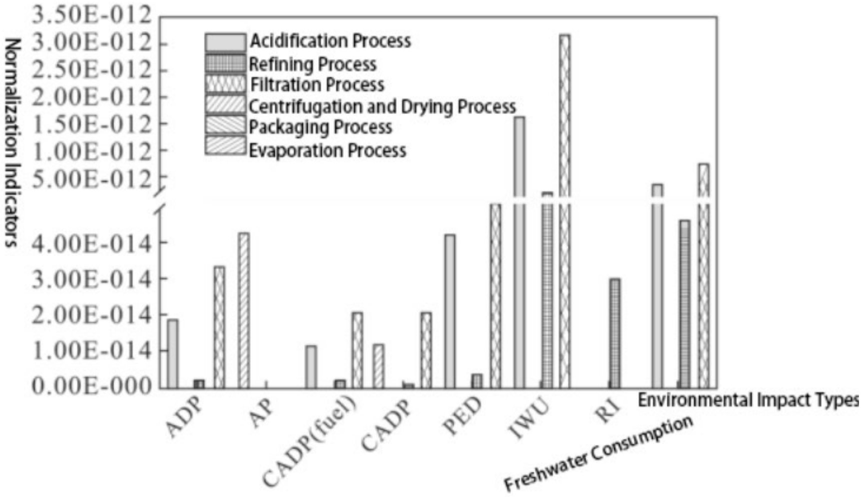

Figure 2: Schematic Diagram of Normalization Processing

4. Lifecycle Results Analysis

Based on the data calculated using the eBalance software, the sensitivity indicators for environmental impacts across different production processes in barium chloride production are illustrated. The results provide a comprehensive overview of the contribution of barium chloride production to various types of environmental impact throughout its lifecycle.

The evaporation stage has a significant contribution to various impact indicators due to coal consumption, followed by the acidification stage where the consumption of concentrated mother liquor and coal is notable. The centrifugation and drying stages also contribute to coal consumption, with acidification operations for producing barium chloride solids having a secondary impact. Coal consumption provides steam and electrical energy for evaporation. To address this, efforts should be made to reduce steam losses and improve thermal conversion efficiency. Utilizing clean energy for generating the steam and electrical power needed for barium chloride production can reduce coal consumption. To sum up, in order to reduce the impact of barium chloride production on various environmental factors, it is necessary to focus on reducing the acquisition of raw materials for this product. The following suggestions are put forward: purchasing low-carbon electricity and heat; purchasing low-carbon raw materials; purchasing and selling raw materials and products in surrounding areas as much as possible; giving priority to low-carbon transportation and low-carbon energy-saving production equipment.

5. Conclusion

In summary, this study used LCA to analyze the environmental impacts associated with barium chloride production processes. By assessing input and output flows across different production stages, the LCA system provided insights into the environmental factors affecting the lifecycle of barium chloride production. The results indicate that industrial water use (EIWU) is the primary environmental impact factor throughout the production cycle, followed by water use (WU) and primary energy consumption (PED). The acidification and centrifugation stages have a higher impact on environmental pollution compared to other stages, highlighting the need for industrial design and production adjustments to address these impacts.

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