TECHNOLOGICAL SCHEME OF LIQUID FERTILIZER PRODUCTION PROCESSES BASED ON LOW-GRADE PHOSPHORITES

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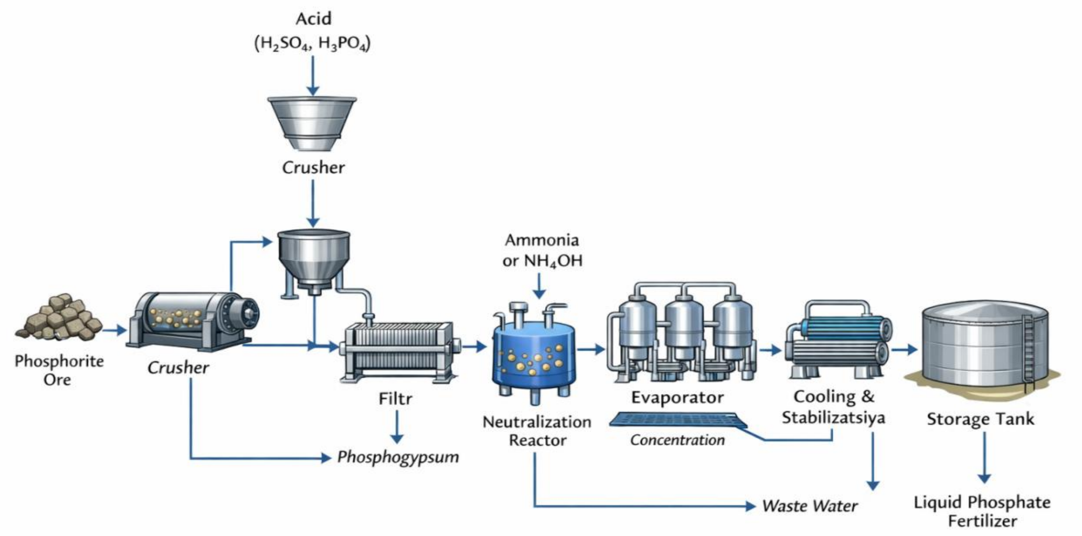
ABSTRACT

This study provides a detailed analysis of the technological processes and industrial apparatus for the production of liquid phosphate fertilizers based on the chemical processing of low-grade phosphorite ores. The study illuminates the theoretical and practical foundations of the technological process schemes for the preparation, grinding, mechanical activation, and acid decomposition of phosphorite ores. The mechanism of formation of water-soluble phosphates resulting from the reaction of calcium phosphate compounds in phosphorite with mineral acids is examined. Additionally, the influence of mass transfer, heat exchange, and reaction kinetics on the technological process during chemical decomposition is analyzed.

Introduction

The process of producing liquid mineral fertilizers from low-grade phosphorite ores consists of several sequential technological stages, each directly influencing the product's quality and the process's economic efficiency. The primary objective of this process is to convert the insoluble calcium phosphate compounds within phosphorite into water-soluble forms using chemical methods. To achieve this, phosphorite ores are treated with various chemical reagents, resulting in the formation of phosphate compounds that are readily absorbed by plants. The technology for processing low-grade phosphorites typically begins with the ore preparation stage. At this stage, phosphorite ores undergo grinding and the separation of the crushed material into granulometric fractions. The grinding process increases the total surface area of the particles and facilitates faster chemical reactions. In practice, ball mills, hammer crushers, or high-energy grinding equipment are used to crush phosphorite ores. The finer the grind, the more effective the subsequent chemical decomposition process will be. In the next stage, the crushed phosphorite ore is sent for mechanical or chemical activation. Mechanical activation creates crystal lattice defects on the particle surface, thereby increasing the substance's chemical reactivity. This significantly accelerates the rate of the acid dissolution process. In some cases, phosphorite ores are also activated through short-term thermal treatment at high temperatures. Such treatment leads to the decomposition of carbonate compounds and loosens the ore's structure. The main stage of chemical processing is the acid decomposition of phosphorites. In this process, the calcium phosphate minerals in the phosphorite react with mineral acids. Sulfuric acid, phosphoric acid, or nitric acid are frequently used as reagents. These reactions result in the formation of water-soluble phosphates. When the calcium phosphate in phosphorite reacts with sulfuric acid, monocalcium phosphate is formed, and calcium sulfate is simultaneously released as a byproduct. The acid decomposition process is usually carried out in reactors equipped with agitators. The reaction's efficiency largely depends on temperature, reagent concentration, mixing speed, and process duration. Under optimal conditions, most of the phosphorus from the phosphorite transitions into the solution, resulting in a liquid phase rich in phosphate ions. A key characteristic of processing low-grade phosphorites is the presence of carbonate compounds. When carbonates react with acids, carbon dioxide gas is released. This can cause foaming in the technological apparatus. For this reason, special technological measures are taken in industrial processes to control gas evolution. These may include reactor gas venting systems or the use of foam-reducing additives. The solution resulting from the acid decomposition is then sent to the filtration stage. During this process, insoluble solid residues are separated from the solution. The solid residues primarily consist of calcium sulfate, silicon compounds, and other mineral components. The filtration process is typically performed using vacuum filters or press filters. Filtration efficiency depends on the solution's viscosity and the size of the solid particles. After filtration, the solution undergoes a neutralization process in the next stage. In this stage, ammonium compounds or other alkaline reagents are added to the solution, resulting in the formation of ammonium phosphates. These compounds are one of the main components of liquid complex fertilizers. The neutralization process involves exothermic reactions, meaning heat is released. Therefore, temperature control is crucial during the technological process. The resulting fertilizer solution can then be sent to the concentration stage. In this process, the water content of the solution is partially evaporated, increasing the concentration of nutrients in the fertilizer. The concentration process is carried out in vacuum evaporators or heat exchangers. The result is a high-concentration liquid fertilizer solution. Ensuring the physical stability of the solution is important in the production of liquid fertilizer. In some cases, crystallization or precipitation can occur in the solution. To prevent this, stabilizers are added to the solution. Stabilizers maintain the ionic balance in the solution and ensure the fertilizer remains stable over a long period. Increasing energy efficiency in low-grade phosphorite processing technologies is also a key issue. At modern production facilities, energy consumption is reduced through the reuse of thermal energy, energy recovery from exhaust gases, and the automation of technological processes. This helps to lower the production cost of fertilizer. Another important aspect of liquid fertilizer production technology is environmental safety. Waste and gaseous products generated during phosphorite processing must not harm the environment. For this reason, industrial enterprises implement gas purification systems, wastewater treatment equipment, and solid waste disposal technologies. The improvement of liquid fertilizer production processes based on low-grade phosphorites is a significant area of scientific research. Modern research is exploring the potential of new catalytic methods, mechanochemical processing technologies, and the use of complex reagents. These methods make it possible to increase the rate of phosphorus transfer into the solution and reduce reagent consumption. Thus, producing liquid mineral fertilizers through the chemical processing of low-grade phosphorites is a complex yet effective technological process. By scientifically optimizing each stage of this process, it is possible to produce high-quality and economically efficient fertilizers. The use of low-grade phosphorites, in turn, allows for a more efficient utilization of mineral raw material resources. The industrial production of liquid fertilizers from low-grade phosphorites is organized based on a complex technological scheme. This process consists of several interconnected stages, including raw material preparation, chemical decomposition, solid and liquid phase separation, neutralization, concentration, and storage of the finished product. Special technological apparatus and equipment are used at each stage. The overall efficiency of the process depends on the proper selection and optimal operating mode of this equipment. The first stage of the technological process is raw material preparation. At this stage, phosphorite ores undergo crushing and screening operations. The crushing process increases the total surface area of the particles by reducing their size, thereby creating favorable conditions for chemical reactions. In industry, the grinding process is often carried out in ball mills. In these apparatuses, grinding occurs with the help of metal balls. As the mill rotates, the balls mechanically impact the phosphorite particles, breaking them down into fine fractions. The crushed phosphorite material is then transferred to the next technological stage via conveyors. At this stage, the material is fed into reactors through special hoppers or dispensers. The function of the dispensers is to precisely control the quantity of raw material, as the amount of phosphorite supplied to the reactor directly affects reagent consumption and process kinetics. The chemical decomposition process is the main stage of the technological scheme. This process is carried out in chemical reactors equipped with stirrers. Because the amount of phosphorite supplied to the reactor directly affects the reagent flow rate and process kinetics. The process of chemical decomposition is the main stage of the technological scheme.



Process Flowchart for Liquid Phosphate Fertilizer Production from Low-Grade Phosphorite

The primary chemical reactions that occur in the reactors involve the decomposition of calcium phosphate within the phosphorite. This process results in the formation of water-soluble phosphate compounds. Heat is released during the reaction, which is why reactors are often equipped with cooling systems. Temperature control is crucial for ensuring process stability. After the chemical decomposition is complete, the resulting mixture is separated into solid and liquid phases in the next stage. This separation is accomplished through filtration or sedimentation methods. In industrial applications, vacuum filters or press filters are commonly used. Vacuum filters enable the rapid separation of solid particles and allow for the process to be carried out continuously. The solid residue obtained from filtration often consists of phosphogypsum or other mineral wastes. These wastes can be utilized as secondary raw materials in certain industries. For example, phosphogypsum is used in the production of building materials. This allows for waste reduction and an increase in the environmental efficiency of the production. The liquid phase, having undergone filtration, is a solution rich in phosphate ions and is sent to the next technological stage - the neutralization process. The neutralization process is conducted in specialized reactors. At this stage, ammonium hydroxide or ammonia is added to the solution, resulting in the formation of ammonium phosphate compounds. These reactions are important for the production of liquid complex fertilizers. The neutralization process is also exothermic, meaning it releases heat. For this reason, the reactors are equipped with cooling or heat exchange systems. Maintaining the temperature at an optimal level helps ensure the quality of the fertilizer solution. If the temperature rises excessively, some phosphate salts may crystallize. The subsequent technological stage is the solution concentration process. During concentration, excess water is evaporated from the solution. This process is carried out in evaporators. Evaporators operate on the principle of heat exchange, converting the water in the solution into steam. As a result, the concentration of nutrients in the solution increases. The evaporators used in liquid fertilizer production often comprise a multi-stage system. This system allows for the efficient use of thermal energy. The steam generated in one stage is used as a heat source in the next, which significantly reduces energy consumption. The concentrated fertilizer solution then undergoes cooling and stabilization processes in the next stage. The cooling process is performed in special heat exchangers. Cooling makes the solution physically stable and suitable for storage. During the stabilization process, special chemical additives may be introduced into the solution. These additives prevent the solution from crystallizing and ensure its long-term stability. This is particularly important when transporting liquid fertilizers over long distances. The final stage of the technological process consists of storing and packaging the finished product. Liquid fertilizers are typically stored in special metal or plastic tanks. These tanks are made from corrosion-resistant materials, and their interiors are protected with a chemically stable coating. During storage, the temperature and chemical composition of the solution are monitored. If necessary, the solution is stirred to prevent the formation of sediment. The finished product is then delivered to agricultural enterprises. If necessary, the solution is stirred, which prevents the formation of a precipitate.

Conclusion

In conclusion, automation systems play a vital role in the technology of liquid fertilizer production. At modern industrial plants, nearly all stages of the process are controlled by automatic control systems. These systems continuously monitor parameters such as temperature, pressure, and reagent consumption. As a result, the production process is carried out in a stable and safe manner. Thus, the technology for producing liquid fertilizer from low-grade phosphorites involves numerous apparatuses and complex technological processes. The proper functioning of these devices and the maintenance of optimal technological parameters are among the main prerequisites for producing high-quality fertilizer. By applying modern technologies, it is possible to obtain highly effective liquid fertilizers even from low-grade phosphorites.

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