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Performance of Baffled Stirred Tank Reactor in Map Mineral Recovery *(Magnesium Ammonium Phosphate)*

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Abstract. In the agricultural and wastewater treatment industries, the formation of Magnesium Ammonium Phosphate (MAP), also known as struvite, is an important process to utilize organic waste and produce value-added phosphate fertilizers. In this context, the use of a stirred tank reactor equipped with baffles is a major concern. This study aims to evaluate the performance of a stirred tank reactor with baffles in the recovery of MAP. Analysis of the experimental results shows that the use of baffles has a significant impact on process efficiency and the quality of the MAP product produced. This study provides a deeper understanding of the role of baffles in maintaining the flow pattern and mixing of raw materials in the reactor tank, thus making an important contribution to the development of more efficient and environmentally friendly phosphate fertilizer manufacturing technology. best phosphate obtained 27%, ph 10, temperature 30oC and molar ratio 1:1:2

Keyword: Molar ratio, pH, Precipitation, RTB, Temperature, Struvite

1. Introduction

A stirred tank flow reactor (RATB) is a device used for continuous chemical processes. This tool is widely used in large industries because of its adjustable capacity. RATB works under stable conditions and is easy to control the temperature. However, the retention time of the reactants in the reactor is limited because the flow rate of the incoming feed and outgoing product is very decisive. This makes the change of reactants per reactor volume difficult to reach a high level, thus the reactor volume required is very large [1].

In chemistry, two popular theoretical models are used to analyze steady-state chemical reactions, namely Continuous Stirred Tank Reactor (CSTR) and Plug Flow Reactor (PFR). The main difference between these two models lies in their assumptions about the concentration of the components involved in the reaction. The CSTR, which takes the form of a tank with a perfect stirrer, assumes that the concentration of all materials in the reactor is equal to the amount of materials removed from the reactor. This model is widely used for reactions with the same phase, as both feedstock and catalyst are liquid. The efficiency of the treatment process is largely determined by the effectiveness of the stirring and mixing of the liquid substances in it. Stirring produces a specific motion of the materials in the vessel, usually with a specific circulation pattern. Mixing, on the other hand, is a process of random dispersion of materials, where one material is mixed with another, although still separated in two or more phases. The main purposes of stirring are to suspend solid particles, mix immiscible liquids and accelerate heat transfer between the liquid and a heat source such as a radiator or heating jacket [2].

Magnesium Ammonium Phosphate (MAP) is an important compound fertilizer in the agricultural industry due to its high nitrogen, phosphorus, and magnesium content. MAP can be produced through various methods, one of which is by using a header tank reactor (RTB). RTB has two types, namely RTB with baffles and without baffles. Baffles are partitions installed inside the tank to improve liquid mixing.Magnesium Ammonium Phosphate (MAP) is an important compound fertilizer in the agricultural industry due to its high nitrogen, phosphorus, and magnesium content. These macro contents are essential for plant growth, so MAP is widely used to increase the yield of various crops. MAP has the chemical formula $MgNH_4PO_4 \cdot H_2O$ and is water soluble, making it easily absorbed by plants.

MAP can be produced through various methods, one of which is by using a header tank reactor (RTB). RTB is a commonly used reactor in the chemical industry for various reaction processes. The MAP synthesis reaction in RTB involves three main reactants: magnesium oxide (MgO), phosphoric acid (H_3PO_4), and ammonia (NH_3). The MAP synthesis reaction is exothermic, i.e. it releases heat. This can increase the reaction rate and conversion of the reactants. The chemical formula of the MAP synthesis reaction is as follows:

$$MgO + 2H_3PO_4 + 2NH_3 \rightarrow MgNH_4PO_4 \cdot H_2O + H_2O$$

The development and improvement of process efficiency for making Struvite or Magnesium Ammonium Phosphate (MAP) is a major concern in the agricultural, wastewater treatment, and nutrient recovery industries. Struvite is a compound formed from the reaction between ammonia, magnesium, and phosphate under appropriate conditions, and has good properties in increasing phosphorus availability to plants and reducing environmental pollution by excessive nutrients. The process of making Struvite through the reaction between ammonia, magnesium, and phosphate in a reactor is a key step in the phosphate fertilizer industry and wastewater treatment [3].

The use of stirred tank reactors has become standard in this process, however, improving process efficiency and product quality continues to be a major focus in research and development. One innovation that has been proposed is the use of baffles within the stirred tank reactor to improve reaction efficiency and the quality of the Struvite product produced. Baffles, or barriers, can affect the flow pattern and mixing of raw materials in the reactor tank, thereby affecting the efficiency of Struvite formation. Previous research has shown that the use of baffles in a stirred tank reactor can provide better results in Struvite formation, both in terms of quality and quantity [4]. With this in mind, this study aims to evaluate the performance of a stirred tank reactor with baffles in Struvite formation. Through an experimental approach and careful analysis, it is expected that the results of this study can contribute to the development of more efficient and quality phosphate fertilizer manufacturing technology and in more sustainable waste management.

2. Methodology

The MAP synthesis reaction occurs between magnesium oxide (MgO), phosphoric acid (H_3PO_4), and ammonia (NH_3) in water. The MAP synthesis reaction can be written as follows:

$$MgO + 2H_3PO_4 + 2NH_3 \rightarrow MgNH_4PO_4 \cdot H_2O + H_2O$$

Whereas in the pH range above 10 not only forms magnesium ammonium phosphate crystals but also forms other minerals such as Bobierrite ($Mg_3(PO_4)_2.8H_2O$) and Brucite ($Mg(OH)_2$) which will form in the pH range 11-12. The solubility of phosphate elements will decrease significantly in the pH range 7-10. [5]. In addition to salt or bittern waste and leachate make struvite from pig manure waste. Because the pig manure waste has almost the same content as bittern but this pig manure waste also contains phosphate. In this study only added magnesium in the pH range 8-9.5. In this process using a centrifugal machine with a speed of 3500 rpm. The results of this study say that the optimum pH for ammonia is in the pH range of 6-7. Struvite crystal formation is best in the pH range 8.5-9 [6].

The formation of magnesium ammonium phosphate in the pH range 7-11.5 and the best pH in struvite crystal formation in the pH range 7.5-9. According to this study, the phosphate and nitrogen

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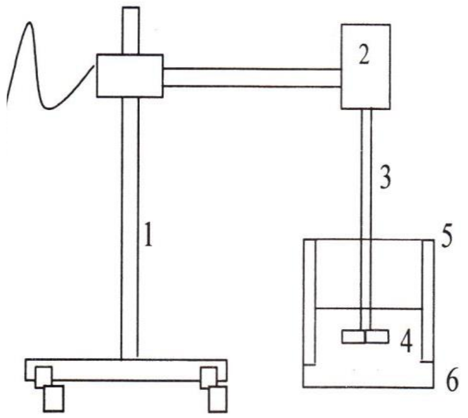
content in struvite will decrease as the pH increases, this can be said when the pH is too alkaline, it means that the phosphate and nitrogen content is small. According to this study, high phosphate content is needed by plants because plants will absorb phosphate as much as 100%. As for the nitrogen content, it must be reduced because the nitrogen element will inhibit the evaporation process in plants, especially fruit tree plants such as apple fruit trees, mango fruit trees, and so on. The phosphate content in struvite will decrease by 90% above pH 8.3. In addition to pH, the temperature that can form struvite is 20-25 °C using a centrifugal machine [7].

The effect of baffles on reactor performance can improve liquid mixing in the reactor by breaking up the liquid flow and creating turbulent flow. Good mixing is important to increase the reaction rate and conversion of reactants. Several studies have been conducted to study the performance of RTB in MAP recovery. One of the studies conducted by Al-Mamun, 2016 showed that baffled RTB resulted in higher reactant conversion [8]. This is due to better mixing in the baffled RTB.



Description:
1.Statip
2. Stirring motor
3. Stirring Rod
4. Stirring Leaf
5. Baffle
6. Tank

Figure 1. Baffle-equipped Stirred Tank toolkit

MAP solution was prepared with a molar ratio of 1:1:1 and 1:1:2 and then put into a stirred tank reactor equipped with baffles. pH was adjusted using KOH. The stirring process was carried out at 200 rpm for 1 hour. After 1 hour the solution was separated, the MAP precipitate formed was analyzed by SEM as well as XRF.

3. Results and Discussion

Figure 2 and 3 below shows the effect of pH on component % for MAP concentration, respectively ratio (1:1:1) and (1:1:2). As shown on the Figure, NH_4OH activity tends to decrease although not significantly, this is because the activity of NH4 and PO4 ions is influenced by the increase in pH . According to (Warmadhewanti and Liu, 2009) said that the removal of ammonium decreases as the pH increases from 10-12 due to the competition of *hydroxyl* ions with PO_4 ions, besides that at pH above 10 not only minerals are formed but also other minerals are also formed such as the brucite mineral $MgOH_2$ which is more dominant at pH 11-12.

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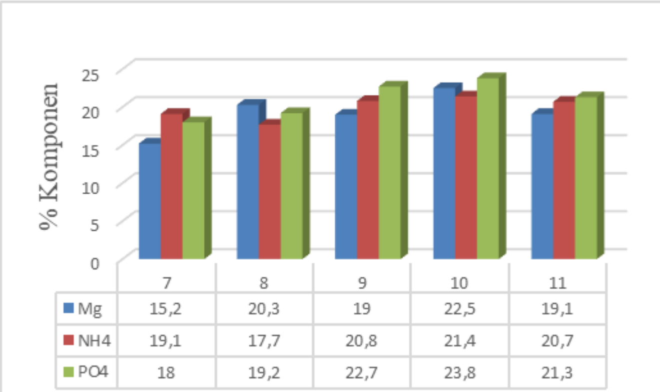

Figure 2. Effect of pH on component % for MAP concentration ratio (1:1:1)

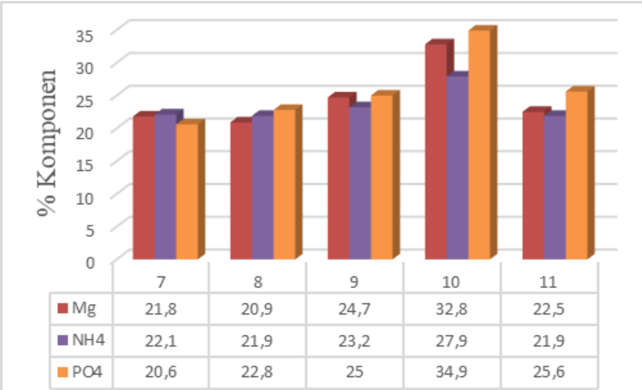

Figure 3. Effect of pH on component % for MAP concentration ratio (1:1:2)

Moreover, the solubility of phosphate will decrease with an increase in pH 10. In addition to pH, the molar ratio comparison in struvite formation also affects the acquisition of MAP. Where the best condition is obtained in the condition of molar ratio 1: 1: 2 with a gain of 27% when compared to the acquisition of MAP with a molar ratio of 1: 1: 1 of 23%. Based on the results of the study, it can be concluded that the baffled RTB has better performance in the acquisition of MAP. This is due to better mixing in the baffled RTB which can increase the reaction rate and conversion of reactants.

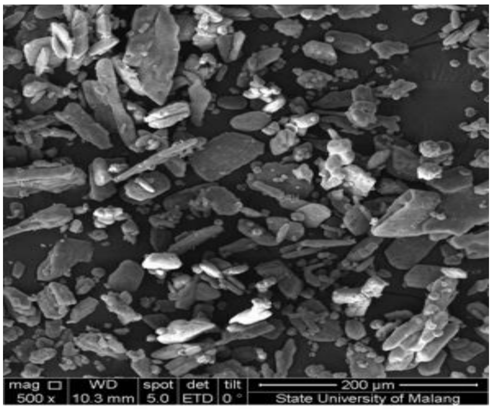

Figure 4. Morphology of MAPs at a molar ratio of 1:1:2

Figure 4 provides a striking illustration of the well-defined crystal shape of the MAP mineral. This clarity suggests a highly controlled growth process, where the baffle played a significant role. In crystal formation, random collisions between particles can lead to misshapen or uneven structures. The baffle likely acted as a barrier, hindering these random interactions and directing the mineral particles to assemble in a more ordered trends. This restricted movement allows the particles to adhere to each other in a specific arrangement dictated by the inherent atomic structure of the MAP mineral, resulting in the well-defined crystal shape observed.

4. Conclusion

Based on the results, the performance of the baffled RTB showed better performance in the acquisition of MAP (Magnesium Ammonium Phosphate) than the RTB without barriers. This is due to better mixing inside the baffled RTB which can increase the reaction rate and reactant conversion. NH4OH activity tends to decrease as pH increases, although not significantly, due to the effect of hydroxyl ion competition with PO4 ions and the formation of other minerals such as MgOH2 at high pH. In addition, the molar ratio also affects the formation of struvite, with the best condition at a ratio of 1:1:2 which produces 27% MAP compared to a ratio of 1:1:1 which only produces 23%.

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