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Struvite Mineral Synthesis from Laundry Waste Water

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Struvite is a white crystal chemically known as magnesium ammonium phosphorus hexahydrate ($MgNH_4PO_4.6H_2O$). This mineral has a hardness of 1.5 to 2 Mohs. *Struvite* is easily soluble under acidic conditions and slightly soluble under neutral and alkaline conditions. In industry, *struvite* is found in the crust of pipes through which hot fluids pass. *Struvite* is often used as fertilizer because of its phosphate content. The formation of *struvite* minerals (hereinafter MAP) from laundry waste water is carried out using an aeration tank. MAP solution is made by reacting laundry waste water with Phosphoric Acid (H_3PO_4) and Ammonium Hydroxide (NH_4OH). The MAP ratio was set at 1:1:1 with a temperature of 20 - 40 oC and an air flow rate of 0.5 - 1.5 liters per minute. The best results were at a temperature of 25oC with an air flow rate of 1 (Liter / minute) with a magnesium content of 10% and phosphorus of 42%.

Keywords: aeration, laundry wastewater, *struvite*

1. Introduction

Laundry waste water is one of the most common wastes. This is due to the lifestyle of young urban mothers who are reluctant to do activities as housewives. Waste or residual use of detergents that enter the aquatic environment will affect water quality and will affect the state of the ecosystem in these waters. The active ingredients contained in many clothes softeners and detergents are *kwaterner* ammonium chloride, LAS, sodium dodecyl benzene sulfonate, sodium carbonate, sodium phosphate, alkylbenzene sulfonate. Besides containing these active ingredients, laundry waste water is also rich in phosphate and magnesium. Surfactants that accumulate in waters will cause oxygen diffusion from the air to be slow, so that little oxygen is dissolved in the water. Phosphate compounds contained in detergents in waters can cause eutrophication, because they can cause aquatic plants to become lush and algae growth to be higher, which if exceeded can cause blooming. The rich phosphate and magnesium content in detergent, so the manufacture of fertilizer from detergent waste in the form of *struvite* fertilizer was developed. *Struvite* (Magnesium Ammonium Phosphate) is a kind of white crystal containing magnesium, ammonium, and phosphate elements. The molecular formula of *struvite* is $MgNH_4PO_4.6H_2O$.

The process of *struvite* formation in general is by reacting Mg^{2+} (magnesium), NH_4^+ (ammonium), dan PO_4^{3-} (phophate) compounds. The elements contained in *struvite* crystals are elements that are also needed by plants. *Struvite* crystals contain phosphorus and magnesium elements that can be used as an alternative material for making *struvite* fertilizer. *Struvite* fertilizer can also be referred to as insoluble fertilizer or slow release fertilizer. This *struvite* fertilizer has several advantages compared to other fertilizers including low solubility to water, easy to make, has a purer content, is easy to use, does not smell, and nutrients are concentrated in one unit.

Struvite used as fertilizer only needs to be added occasionally to plants because of its slow release nature [1] In this study, the *struvite* formation process occurred in a bubble tank using a molar ratio of 1:1:1. According to [2], the minimum molar ratio of *struvite* or magnesium ammonium phosphate is 1:1:1. Based on research conducted by [1], the molar ratio of 1:1:1 produces a crystal shape with clear line angles. The formation of *struvite* is also influenced by pH, for pH itself according to research conducted by [3], the optimum pH in the formation of *struvite* crystals is pH 9. The best *struvite* is in the pH range of 9-10. This is because at pH 7 and 8 the formation of *struvite* minerals can occur but it is not yet said to be optimal, while above pH 10 will tend to form Mg ($]OH)_2$ thus reducing the availability of Mg^{2+} ions which can reduce the productivity of *struvite* crystal formation. Crystal growth is also influenced by the air flow rate.

At large air flow rates experience a slowdown. The faster the contact between the constituent components of *struvite* results in imperfect crystal growth. Stirring at a large rate results in reduced induction time and nucleation will occur faster [1]. The advantage of this research is that the raw material for detergent liquid waste containing magnesium and phosphate is unused waste and can reduce environmental problems. *Struvite* as an ingredient for making fertilizer is also an advantage for the authors because later the *struvite* produced can meet the quality requirements as fertilizer raw material and is expected to be an alternative to increase fertilizer production in Indonesia. In addition, detergent liquid waste can reduce dependence on the manufacture of fertilizers containing phosphorus from phosphate rock raw materials which if this phosphate rock is taken continuously will run out quickly. Therefore, the phosphate and magnesium content in this detergent liquid waste can be utilized as one of the ingredients to form *struvite* fertilizer by reacting it with Ammonium compounds (NH_4).

2. Methodology

The materials used in this study are laundry wastewater obtained from personal laundry waste and laundry services with Mg levels of 5220 mg/L, supporting materials for the *struvite* mineral formation process are phosphoric acid (H_3PO_4) 85%, ammonium hydroxide (NH_4OH) 25%, potassium hydroxide (KOH) 85% and distilled water.

The MAP solution with a concentration of (1:1:1) was put into the aeration reactor. The air flow rate was run at 0.5; 0.75; 1; 1.25; and 1.5 liters per minute. KOH was added drop by drop until the pH of the solution reached pH 9 and was constant. After that, the precipitate formed was filtered and then dried at room temperature. The precipitate obtained was analyzed by XRF to determine the percentage of Mg and P in *struvite* and SEM analysis to determine the characteristic shape of the resulting *struvite*.

3. Result & Discussion

The relationship of temperature (°C) to the elemental magnesium content (weight %) with air flow rate 0.5; 0.75; 1; 1.25; 1.5 (Liter/minute) has no significant effect. The greater the temperature (°C), the content of magnesium elements (weight %) in *struvite* will increase, where magnesium can affect the level of saturation of the solution and magnesium plays an important role to enhance the reaction process of *struvite* formation. This is because temperature can affect the solubility of *struvite*.

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Table 1. The results of the analysis of Magnesium & Phosphate content in *struvite* minerals formed

Suhu (°C)	**Unsur (% Berat)**	**Laju Alir Udara (Liter/menit)**				
		0,5	**0,75**	**1**	**1,25**	**1,5**
20	Mg	8,6	8,7	9,9	9,4	8,4
	P	40,5	41,2	41,7	40,6	39,7
25	Mg	8,7	9,2	10	9,6	8,6
	P	41	41,6	42	41,4	40,7
30	Mg	9,3	9,4	10,1	9,8	8,7
	P	41,8	42,4	43,2	42,6	41,6
35	Mg	9,5	9,6	10,4	20	9,4
	P	42,5	43	43,6	43	42,2
40	Mg	9,8	10,2	10,6	10,3	9,6
	P	44	45,3	46	44,9	43,7

According to [3], high temperatures can also affect the nature of the crystals formed, *struvite* turns faster into the mineral *newberite* ($MgHPO_4.3H_2O$) when the temperature is high. This is what causes the elemental Mg content (weight %) to increase with increasing temperature. The following is explained in Figure 1

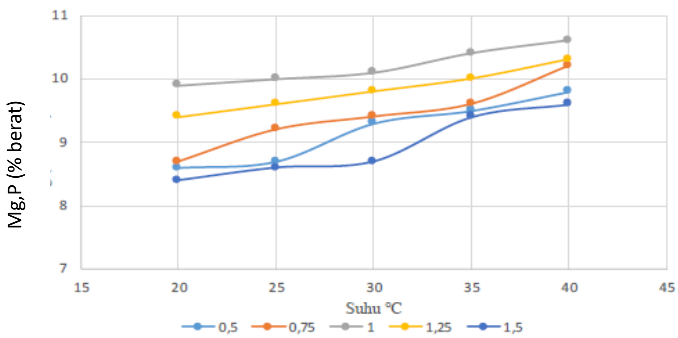

Figure 1. Relationship between temperature and Mg and P yields

In Figure 2, it can be seen that the relationship between the air flow rate (liter/minute) and the content of magnesium elements (weight %) as well as phosphates with a temperature of 20; 25; 30; 35; 40 (°C) has a significant effect. According to [4], this is because the nucleation stage of *struvite* crystal formation is influenced by the fluid turbulence process, if the aeration rate increases, the fluid turbulence process in the reactor is getting higher which causes the induction time to decrease and the *struvite* crystal nucleation process becomes faster. According to [5], if the aeration rate exceeds the optimum aeration rate, the magnesium content (weight %) will decrease due to the process of fluid turbulence that is too high in the reactor, causing crystal breakage and decreasing *struvite* crystal stability.

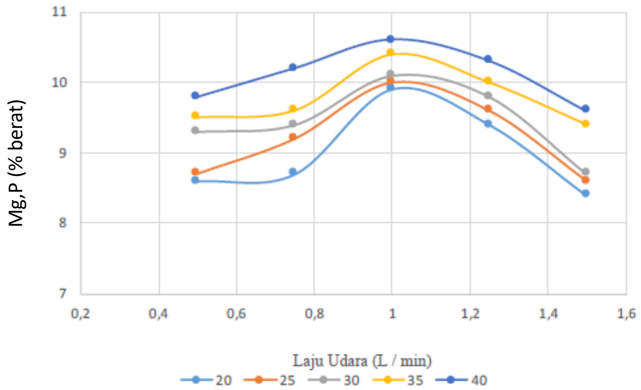

Figure 2. Relationship of air flow rate to Mg and P yields

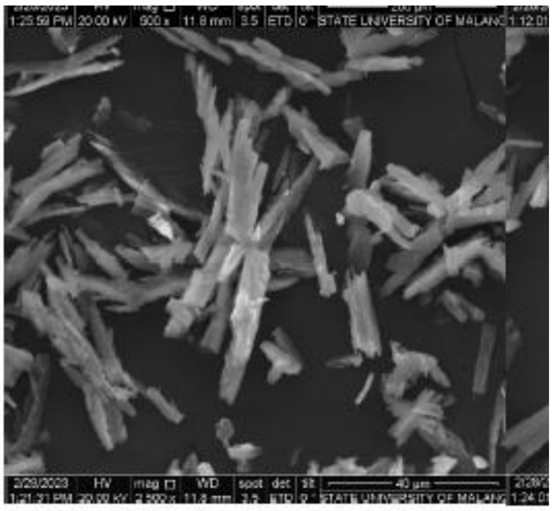

Figure 3. SEM analysis results of *struvite* crystals at 25°C with air rate 1 (liter/minute)

In Figure 1 above is the result of SEM analysis on *struvite* crystals that have the best content of (weight %) magnesium and (weight %) phosphorus. According to [6], pure *struvite* crystals will have a rod shape with pointed ends and a clean surface without defects. According to [7], *struvite* crystals are irregular flakes measuring 20 µm. The *struvite* crystals obtained from the results of this study are rod-shaped with pointed and non-pointed ends. The characteristics of *struvite* crystals are of course influenced by the content contained in the *struvite* crystals. The smaller *struvite* crystal size has a larger total surface area so that it will accelerate the solubility of a substance and the absorption process of fertilizer nutrients can take place faster. Given that *struvite* is a slow-release fertilizer, so the larger crystal size causes nutrients in the fertilizer to be absorbed more slowly by plants [1].

4. Conclusion

The formation of *struvite* from detergent liquid waste produces the best magnesium and phosphorus acquisition at a temperature of 25oC with an air flow rate of 1 (Liter / minute). This is because during these operating conditions, the *struvite* obtained has a content (weight %) of magnesium which is 10% and a content (weight %) of phosphorus which is 42%. The addition of magnesium to the MAP solution results in an increase in the acquisition of magnesium and phosphorus but can form other compounds so that the purity of *struvite* is reduced as shown in the SEM results. The higher the air flow rate in the aeration process resulted in unstable and broken crystals due to the high collision between crystals. Further research is needed to determine the effectiveness of *struvite* as fertilizer to plants.

5. References

[1]. Edahwati L, Sutiyono, Anggriawan RR. Pembentukan Pupuk Struvite dari Limbah Cair Industri Tempe dengan Proses Aerasi. J Teknol Lingkung. 2021;22(2):215–21.

[2]. Zhang X, Hu J, Spanjers H, van Lier JB. Struvite crystallization under a marine/brackish aquaculture condition. Bioresour Technol [Internet]. 2016;218(July):1151–6. Available from: http://dx.doi.org/10.1016/j.biortech.2016.07.088

[3]. Ariyanto E, Ang HM, Sen TK. Impact of various physico-chemical parameters on spontaneous nucleation of struvite (MgNH<inf>4</inf>PO<inf>4</inf>.6H<inf>2</inf>O) formation in a wastewater treatment plant: kinetic and nucleation mechanism. Desalin Water Treat. 2014;52(34–36):6620–31.

[4]. Ohlinger BKN, Member S, Young TM, Member A, Schroeder ED. K INETICS E FFECTS ON P REFERENTIAL S TRUVITE. J Environ Eng. 1999;125(August):730–7.

[5]. Rahaman MS, Ellis N, Mavinic DS. Effects of various process parameters on struvite precipitation kinetics and subsequent determination of rate constants. Water Sci Technol. 2008;57(5):647–54.

[6]. SUGUNA K, THENMOZHI M, SEKAR C. Growth, spectral, structural and mechanical properties of struvite crystal grown in presence of sodium fluoride. Bull Mater Sci [Internet]. 2012 Aug 5 [cited 2018 Aug 12];35(4):701–6. Available from: http://link.springer.com/10.1007/s12034-012-0322-6

[7]. Perwitasari DS, Edahwati L, Sutiyono S, Muryanto S, Jamari J, Bayuseno AP. Phosphate recovery through struvite-family crystals precipitated in the presence of citric acid: mineralogical phase and morphology evaluation. Environ Technol (United Kingdom) [Internet]. 2017;38(22):2844–55. Available from: http://dx.doi.org/10.1080/09593330.2017.1278795

[8]. Adiman, (2020), 'Mineral *Struvite* dari Batuan Dolomite dengan Reaktor Kolom Sekat, *jurnal Teknik Kimia*, Vol. 14, No. 02.

[9]. Kristell, S., (2015), *Understanding Struvite Crystallisation and Recovery*, Cranfield University PRESS, United Kingdom

[10]. Kunarso, Muhammad, Z., Lilik, M., Sri, Y.W. dan Nurindahsari, N.L., (2021),' Kandungan Pencemar Detejen Dan Kualitas Air Di Perairan Muara Sungai Tapak, Semarang', *Indonesian Journal of Oceanography,* Vol.03, No.01.

[11]. Rohiman, A., (2020), 'Comparation of Pressed Powder Pellet and Fused Glass Bead Preparation Techniques for Mayor ElementsAnalysis of Rock Samplesusing X-Ray Fluorescence (XRF)', *Indonesian Journal of Physics*, Vol.31, No.2