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Artikel Penelitian

Nano-MgO Synthesis and Characterization using $MgCl_2$ via Precipitation Method

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ABSTRACT

Nanoparticles have offered numerous benefits in various life sectors, leading to significant advancements and optimization in the development of nanoparticles over the past decade. The challenge revolves around the synthesis process and pricing of nanoparticles. This study investigated the production of a novel type of nanoparticles, specifically nano-MgO. Nano-MgO synthesized via a precipitation method involving technical-grade magnesium chloride ($MgCl_2$) as the starting material and ammonium hydroxide (NH_4OH) as the precipitating agent. The objective of this study was to fine-tune the synthesis procedure by altering the concentration of NH_4OH (0.5% and 1%) and to assess the properties of the resulted nanoparticles in terms of their suitability for applications. The properties of the synthesized nano-MgO were identified using X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), iodine number adsorption, and Brunauer-Emmett-Teller (BET) analysis to evaluate the oxides content, minerals formed and the crystallinity, adsorption capacity, surface area, and porosity. The findings show that, compared to 1%, a concentration of 0.5% NH_4OH produced a superior MgO. A nano-MgO with 87.1% purities (of dominantly periclase phase), with the average crystallite grain size of 11.383 nm was formed. The iodine adsorption capacity of 243.01 mg/g, BET surface area of 43.4298 m^2/g , and average pore diameter of 9.0002 nm were achieved, indicating formation of nanoporous structure, well-suited for a wide range of industrial use. Whereas when using 1% NH_4OH , the purity only reached 83% (of the same dominant phase) with an average crystallite grain size of 11.691 nm, and iodine number of 197.98 mg/g. In addition, its effectiveness is also evidenced by the increased bioavailability of vanadium metal in red mud which reached 259.496 mg/kg. Thus, this study demonstrated that the precipitation process employing 0.5% NH_4OH is the most effective method for producing high-quality nano-MgO with superior characteristics. Unfortunately, this research did not conduct the controlling of the nano-MgO particle size distribution, therefore future of this research is adding the chelating agent in the process precipitation to control the particle distribution

Keywords: Bioavailability, $MgCl_2$, Nano-MgO Synthesis, Precipitation

1. INTRODUCTION

Recent decades have seen the rapid development of nanoparticles, creating significant opportunities in numerous application fields such as adsorption process (Singh, 2022; Veeranna et al., 2021), catalysis (Moghadasli et al., 2025), and the medical sector (Dejene, 2024). Nanoparticles have some unique characteristics in their size, shapes, surface area, purity, and crystallinity, depending on the purpose of synthesis and their application.

One notable nanomaterial that has garnered significant attention is Magnesium Oxide (MgO). This material is distinguished by its distinct physicochemical properties, including a large surface area, excellent thermal stability, and high reactivity (Saberli et al., 2024). MgO's properties make it a potential candidate for applications in pollutant removal (Perera et al., 2024), heterogeneous catalysts, biomedicine (Abinaya & Kavitha, 2023), specifically as antibacterial agents drug delivery systems (Saberli et al., 2024) and agricultural process (Elizabeth, 2019).

Meeting the growing industrial demand requires the highly efficient and cost-effective synthesis of nanoparticles (Abuzeid et al., 2023; Saleh & Hassan, 2023). Unfortunately, complicated and costly synthesis processes (Ali, 2018), which require advanced equipment, frequently hinder large-scale production (Mayekar, 2024).

Furthermore, obstacles including high energy consumption, lengthy production periods, and the difficulty of regulating the nanoparticle size are barriers to their use (Ying et al., 2022).

There are many process methods to produce MgO nanoparticles. Sol - Gel produces uniform and high-purity MgO nanoparticles (Sim et al., 2024), precipitation is simple and cost-effective for Nano MgO production (Taourati et al., 2020) , hydrothermal method produced well-crystallized nanoparticles with a controlled nano MgO morphology (Abinaya & Kavitha, 2023), among other methods with various results was found.

One of the most promising synthesis techniques is the precipitation method (Buraso et al., 2018; Li et al., 2018, 2018; Mayekar, 2024). This approach is distinguished by its simplicity, low production expenses, and its ability to regulate the dimensions of nanoparticles (Buraso et al., 2018; Mayekar, 2024). The precipitation method can be fine-tuned by adjusting parameters like pH, temperature, and precursor concentration to produce nano MgO particles with the desired dimensions and structure (Mayekar, 2024; W. Wang et al., 2007). Precipitation method is not selective for kind of chemicals precursors, especially for technical grade chemicals. MgCl₂ Technical grade is not familiar with raw material of nano-MgO, Technical grade chemicals is relatively inexpensive and easily obtainable, can substantially reduce manufacturing costs. However, to control the quality of nanoparticle, NH₄OH is the correct precipitation process with varying concentration. The precipitation method and MgCl₂ technical grade precursor makes it an attractive option for mass-producing MgO nanomaterials on a large scale, ensuring that the materials meet quality and performance standards.

The objective of this study is to obtain the optimal variation of NH₄OH concentration (0.5% and 1%) as a precipitator of nano-MgO synthesized using technical grade MgCl₂. The synthesized from this process is characterized to identify the purity, size, crystallinity and adsorption capacity. Furthermore, the application of nano-MgO to improve the bioavailability of metal is tested. The results are expected to contribute to the development of an efficient and cost-effective method for the fabrication of nano-MgO. Future research on nano-MgO can include the addition of a chelating agent to control the distribution of particles because the distribution of particles is one of the important characteristics of nanoparticles.

2. MATERIAL AND METHOD

2.1. Material

Nano – MgO synthesized using Magnesium Chloride (MgCl₂) technical grade as the precursor and Ammonium Hydroxide (SAP Chemicals, 25%) as the precipitant. Magnesium Chloride technical grade is a form of magnesium chloride (MgCl₂) used for industrial or commercial applications, not for high purity food, and laboratory purposes.

2.2. Method

2.3.1. Synthesis of MgO Nano Particle

MgO nanoparticles were synthesized via the precipitation method, utilizing MgCl₂ as a precursor and NH₄OH as a precipitating agent (Wang et al., 2007). Figure 1. Describe the steps involved in nano MgO synthesize.

The process starts with dissolving MgCl₂ to create a 2 M solution, whereupon 0.5% or 1% NH₄OH is gradually added until a white precipitate of Mg(OH)₂ forms during a precipitation reaction. The precipitate was washed using distilled water to remove impurities, then air dried and calcined at 600°C for 4 hours to produce MgO nanoparticles.

2.3.2. Characterization of MgO Nano Particle

The characterization of MgO nanoparticles synthesized with 0.5% NH₄OH and 1% NH₄OH was conducted using X-Ray Fluorescence (XRF) to determine the purity of the MgO samples. In the other hand, to evaluate the crystallinity of MgO nano particle X-Ray Diffraction (XRD) analysis was performed. To evaluate their adsorption performance, the Iodine number was measured, which indicates the capacity of the nanoparticles to adsorb iodine molecules, reflecting their surface activity and porosity. Additionally, the Brunauer-Emmett-Teller (BET) test was employed to analyze the surface area and pore structure of the nanoparticles, providing insights into their adsorption efficiency and overall effectiveness.

2.3.3. Application of Nano-MgO for Improving Metals Bioavailability

Additional characterization to evaluate the performance of nano MgO was then applied in improving the bioavailability of vanadium metal in red mud. The amount of nano MgO application in red mud is 0,5 g/kg red mud. Bioavailability metal evaluation will be conducted for 7, 14, 21, and 28 days. Red mud will be analyzed

using sequencing extraction method for bioavailability metals test (Jena et al., 2013). This method explains the vanadium speciation procedure, where bioavailability metals speciation contains exchangeable and carbonate species. To determine the exchangeable and carbonate metals species, we used MgCl_2 and CH_3COONa to extract the vanadium from red mud.

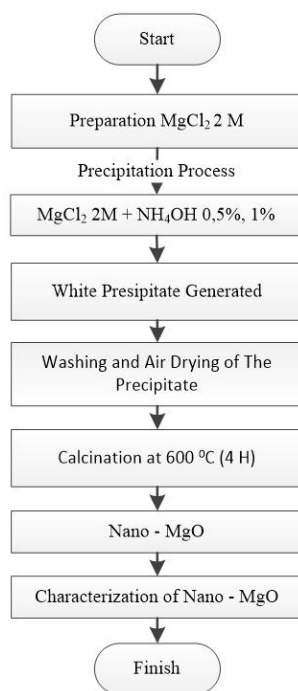


Figure 1. Diagram of MgO nano particle synthesise

3. RESULTS AND DISCUSSION

3.1. Chemical Composition

Analysis with the X-Ray Fluorescence (XRF) method was carried out to determine the chemical composition and impurity content of MgCl_2 as the starting material (precursor) and MgO produced after the synthesis process through the precipitation method. XRF testing on MgCl_2 precursors aims to identify the composition of the element magnesium (Mg) contained in technical MgCl_2 which will be used in the synthesis process. The XRF test results show that the elemental Mg content in technical MgCl_2 is 1.5%. After synthesizing with the precipitation method, two nano MgO samples were obtained, which have 76% for nano MgO using 1% NH_4OH and 78.1% for Nano MgO using 0,5% NH_4OH Mg content, respectively.

This significant increase in Mg content indicates that the precipitation process successfully converts MgCl_2 into MgO with high efficiency, while reducing impurities that may be present in the starting material. This process also indicates that most of the chlorine (Cl) and other impurities have been successfully removed during the synthesis. Of the two samples produced, Nano MgO using NH_4OH 0.5% shows a higher Mg content (78.1%) compared to Nano MgO using NH_4OH 1% (76%), so it can be concluded that NH_4OH 0.5% is a more optimal condition in this synthesis process.

Table 1. Chemical oxide composition MgO with NH_4OH 1% and NH_4OH 0,5%

Oxide Compound (%)	NH_4OH 1%	NH_4OH 0,5%
MgO	83	87.1
SiO_2	5.6	0.8
P_2O_5	4.1	2.7
CaO	1.6	1.7
V_2O_5	0.58	0.36
MnO	1.6	2.1
Fe_2O_3	0.2	0.08

Oxide Compound (%)	NH ₄ OH 1%	NH ₄ OH 0,5%
CuO	0.51	0.36
ZnO	0.3	-
ZrO ₂	3	3.9
SnO ₂	3.49	0.6
Re ₂ O ₇	-	1.6



Figure 2. (A) Nano MgO with NH₄OH 1%, (B) Nano MgO with NH₄OH 0.5%

The effectiveness of the variable precipitators can be evaluated based on the oxide compounds formed. The purity of the MgO compounds can be analyzed through X-Ray Fluorescence (XRF) testing, which also identifies the presence of impurities in the sample. Based on Table 1, the MgO content in the Nano MgO using 1% NH₄OH and 0.5% NH₄OH samples is 83% and 87.1%, respectively. This significant difference in the MgO concentration indicates that the use of a lower NH₄OH precipitator concentration (0.5%) results in higher MgO purity compared to the 1% concentration. The use weak base of NH₄OH as a precipitator has several advantages compared to other precipitators, such as alkaline compounds. One of the main advantages is that NH₄OH does not precipitate other unwanted compounds during the precipitation process. For example, alkaline precipitators may precipitate hydroxide compounds of alkali metals, which may interfere with the purity of the final product (Dong et al., 2017). Compared to the size aspect, employing a weak base is not as effective as utilizing an alkaline base (Zhang et al., 2006).

In addition, the use of lower concentrations of NH₄OH proved to be more effective in producing MgO with higher purity (Dong et al., 2017). However, the yield decreases when using a low concentration of NH₄OH as a precipitant because the solution cannot reach the necessary level of supersaturation required for the efficient formation of Mg(OH)₂. Supersaturation drives the nucleation and growth of solid particles, and lower NH₄OH concentrations limit the availability of hydroxide ions (OH⁻), slowing down the reaction between Mg²⁺ and OH⁻. Despite the reduced output, lower NH₄OH concentrations allow for better control over the reaction rate, leading to more uniform and smaller Mg(OH)₂ particles, which ultimately form high-quality MgO with improved purity and reduced agglomeration (Schwaminger et al., 2020). This trade-off between yield and quality is crucial in nanomaterial synthesis, where particle size and morphology are often prioritized over quantity. Controlled reaction rates can improve the homogeneity of the nanoparticles, and prevent agglomeration (Nafsin et al., 2016).

3.2. Crystallinity Analysis

It is critical to identify MgO nanoparticles crystal phase because they will affect the nanoparticle's performance based on its crystal type. Based on Fig. 2 which shows the XRD graph, using the Match software, it will be obtained that the dominant phase of each MgO nanoparticle is Periclase. Periclase is a crystal phase of MgO with a cubic structure. Periclase has strong mechanical properties because it has a compact and rigid structure with 160 GPa compression (Smyth et al., 2000). The purity of the nano MgO NH₄OH was 0.5% and 0.1% in the periclase phase, respectively, at 78.20% and 74.13%. The rest is the unidentified peak area where the potential is that other phases are formed from MgO such as amorphous forms and other impurities.

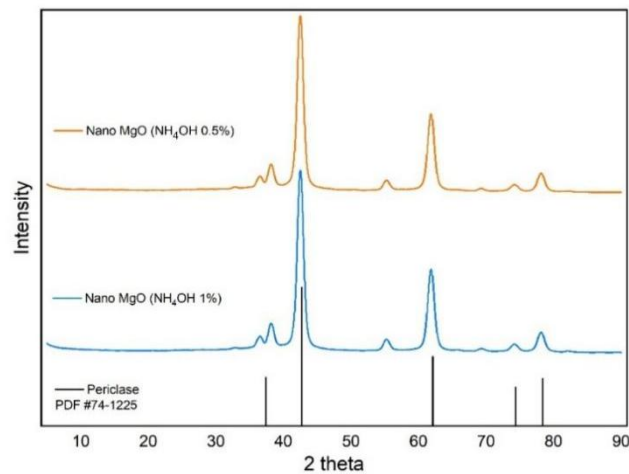


Figure. 3. XRD Graphic of nano MgO with 0.5% and 1% of NH₄OH

Recent research found MgO peaks around 36.7°, 42.89°, 62.2°, 74.5°, and 78.4° (Balaba et al., 2024). These results based on Figure 3. are similar to the peaks of MgO nanoparticles in this study. The dominant peak points of nano MgO NH₄OH 0.5% are 38.06°, 42.44°, 55.04°, 61.68°, 73.94°, and 77.84° respectively. The dominant peak points of nano MgO NH₄OH 1% are 38.1°, 42.36°, 55.18°, 61.68°, 73.98°, and 77.94° respectively. The peak point will be analyzed to calculate the grain size of the crystal using the Debye-Scherrer equation.

Table 2. Peak list Nano MgO using 1% and 0.5% of NH₄OH

Sample	2θ	Intensity	FWHM	Crystallite Size (nm)	Average Size (nm)
NH ₄ OH 0.5%	38.06	121.1	0.5510	15.923	11.691
	42.44	978.6	0.7130	12.478	
	55.04	55.6	0.9746	9.596	
	61.68	384.3	0.6321	15.281	
	73.94	40.9	1.2363	8.397	
	77.84	117.3	1.2587	8.469	
NH ₄ OH 1%	38.1	106.7	0.6321	13.881	11.383
	42.36	1017.4	0.8584	10.362	
	55.18	70.8	0.8882	10.536	
	61.68	396.1	0.6321	15.281	
	73.98	48.8	1.2393	8.379	
	77.94	125.3	1.0822	9.858	

The Debye-Scherrer formula is used for identifying the size of MgO nanoparticles based on its crystal, periclase. The formula considers a Scherrer constant (*k*) of 0.94, wavelength (λ) of 1.5406 Å, Full Width at Half Maximum (β) in radians, and peak angle θ . The details of the calculation results can be seen in Table 2. Nano MgO using NH₄OH precipitator 0.5% and 1% both have shown that the crystal size ranges from 8-16 nm with a better average size optimum NH₄OH 0.5% with 11.691 nm. Then, using purity considerations, nano MgO using 0.5% NH₄OH as a precipitator is the optimal variable with 78.20%.

3.3. Iodine Number

Assess the capabilities of nanoparticles through a method such as adsorption. Typically, amorphous particles known as nanoparticles possess a substantial adsorption ability due to their extensive pore structures. Besides their extremely small size, the presence of these pores can enlarge the surface area of the nanoparticles. Therefore, adsorption methods play a crucial role in assessing the capabilities of nanoparticles. The iodine number is associated with the surface area and pore characteristics of the material. Because of their small size, the nanoparticles possess an exceptionally large surface area, thereby enabling them to absorb a substantial amount of iodine.

The treatment of nanoparticles using the iodine adsorption method, also referred to as the iodine number, involves dissolving 1 g of nano MgO in 1 mol/L iodine solution. The findings obtained are the adsorption capacity or iodine number of nano MgO.

Table 3. Iodine Number Nano MgO using 1% and 0.5% of NH₄OH

Materials	Iodine number	units
NH ₄ OH 1%	197.98	mg/g
NH ₄ OH 0.5%	243.01	mg/g

According to the provided data, MgO nanoparticles produced with 0.5% NH₄OH as a precipitator exhibited a greater iodine adsorption capacity (243.01 mg/g) than MgO produced with 1% NH₄OH (197.98 mg/g). The data in Table 1 shows a direct correlation between the increase in magnesium oxide concentration and the increase in adsorption capacity. The adsorption capacity is also influenced by factors such as surface area, pore distribution, and particle morphology, which are established during the synthesis process. At lower magnesium oxide concentrations, adding 0.5% ammonia in water may enhance the formation of smaller particles with improved dispersion, thereby increasing the number of active sites available for adsorption. At concentrations of 1% NH₄OH, particle agglomeration or a decrease in effective surface area can occur, leading to reduced adsorption capacity. Optimizing the synthesis conditions of MgO nanoparticles, particularly the concentrations of precursors and precipitators, is essential for maximizing adsorption efficiency.

3.4. Surface Area

According to XRF, XRD and Iodine Number analysis, Nano MgO using 0.5% NH₄OH is optimum variation. Thus, surface area analysis is conducted only to this material using two different techniques: the Brunauer-Emmett-Teller (BET) method and the Langmuir surface area calculation. According to Table 4. MgO has a BET surface area of 43.4298 m²/g, alongside a Langmuir surface area of 85.9954 m²/g. Previous research states the surface area of nano MgO ranges from 1.5 - 87.7 m²/g (Kim et al., 2013), and 35.09 - 116.67 m²/g (Sadgar et al., 2020).

Table 4. Surface Area Results for Nano MgO NH₄OH 0.5%

Parameters	Value	Units
BET Surface Area	43.4298	m ² /g
Langmuir Surface Area	85.9954	m ² /g
Adsorption Average Pore Diameter	9.0002	nm
Desorption Average Pore Diameter	11.6876	nm
Adsorption Pore Volume	0.097719	cm ³ /g
Desorption Pore Volume	0.126	cm ³ /g
Average Particle Size	138	nm

The difference arises from the distinct assumptions each technique makes when calculating the surface area. The BET method, developed by Brunauer Emmett and Teller relies on multilayer gas adsorption, typically nitrogen onto a material's surface, making it particularly effective for porous materials. This results in a lower surface area measurement due to its consideration of adsorption occurring in the gas layers. Conversely, The Langmuir method assumes monolayer adsorption and generally yields higher surface area values because it accounts for adsorption only on the first layer. Regarding the BET and Langmuir approaches, the area plotting graph can be seen in Fig. 4.

The BET Surface Area Plot graph shows a linear relationship between the relative pressure (p/p^0) and the nitrogen adsorption function in the range of 0.05-0.20, which agrees with the BET model assumption that adsorption occurs in a multilayered manner but is dominated by the initial monolayer formation. This model is suitable for heterogeneous surfaces and accounts for the possibility of forming more than one layer of adsorbate molecules. In contrast, the Langmuir Surface Area Plot graph depicts a linear relationship between the absolute pressure (p) and p/Q ratio only at low to moderate pressures (<300 mmHg), if adsorption only occurs in a single layer on a homogeneous surface with no interaction between adsorbate molecules. Both graphs show that MgO has a surface that can be validly analyzed by the monolayer approach (Langmuir and BET), but the BET model can better explain the adsorption behavior over a wider pressure range, including the potential for multilayers. Therefore, for general surface area characterization, the BET model is often considered more representative, while the Langmuir model is more suitable for evaluating the monolayer affinity and capacity under low-pressure conditions.

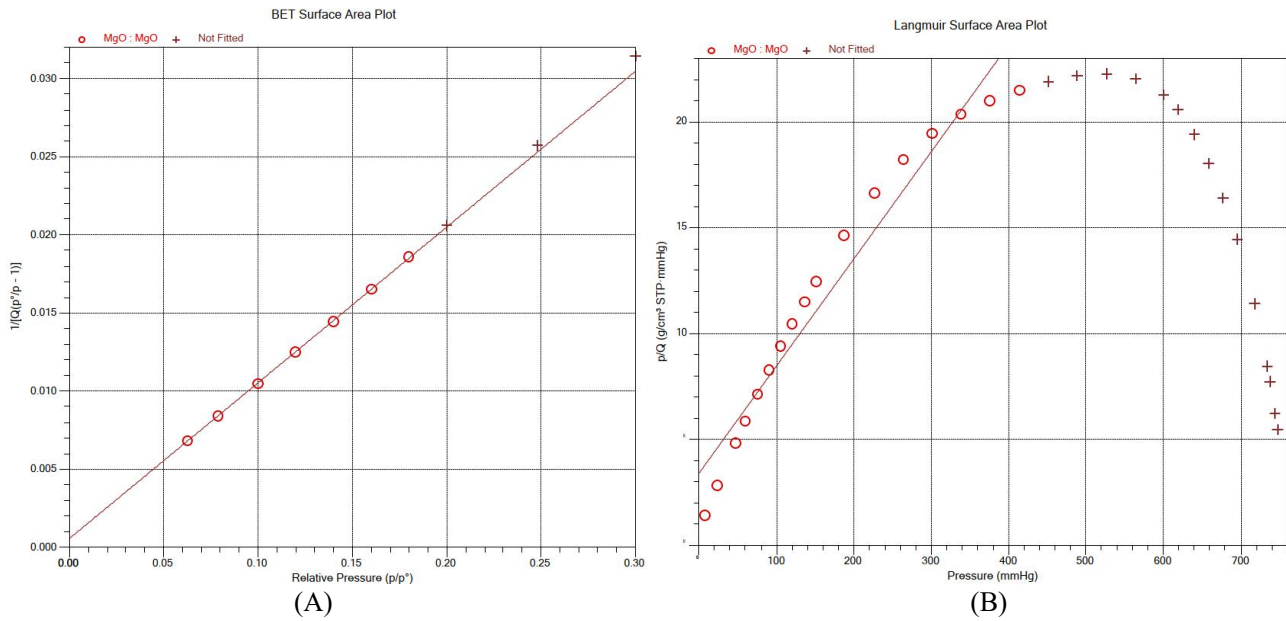


Figure 4. (A) BET surface area plot (B) Langmuir Surface Area Plot

Research indicates that the pore diameter of nano MgO is approximately 6.721 nm (Sreekanth et al., 2021), placing it within the category of mesopores, which ranges from 2 to 10 nm (Saputra et al., 2024). Other studies suggest that mesopore size can also fall within the 2-50 nm range (Sreeharsha et al., 2022). Mesopores are particularly useful for drug targeting and delivery, as their small size allows nanoparticles, measuring 2-50 nm in diameter, to effectively bind to specific receptor sites and produce the desired therapeutic effect (Florek et al., 2017). The mesopores' ability to trap and stabilise non-crystalline drug molecules also enhances the drug's dissolving rate (Jafari et al., 2019).

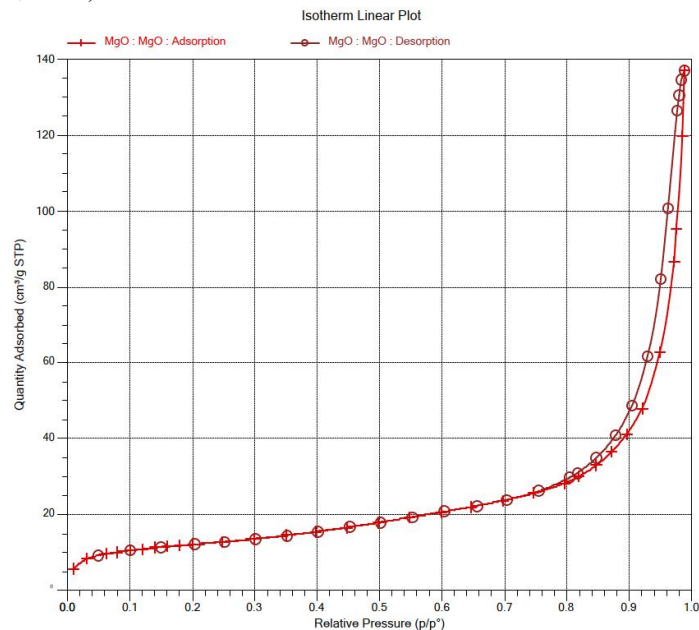


Figure 5. Hysteresis loop of nano MgO with 0.5% of NH_4OH

In the pore volume test, the total volume of pore space per gram of material is measured, where the pore volume during desorption ($0.126 \text{ cm}^3/\text{g}$) is also larger than during adsorption ($0.097719 \text{ cm}^3/\text{g}$) again. There is different value of adsorption and desorption, where desorption is bigger because fluid in the pore is harder to vaporize as it requires lower pressure to break the meniscus curvature (K. Wang et al., 2025). This case is related to hysteresis loop based on Figure 5. The Graphic has a little loop hysteresis between adsorption and desorption, so that it will be recognized that mesopores are more dominant in the materials. This difference indicates that the desorption process tends to reveal more pore space that is not accessed during adsorption. both in terms of size and

volume. The average particle size is determined using the surface and pore analysis data obtained this time. The approach is directly derived from the calculation results, making it suitable for use as a reference for comparable average particle size assessments. The size of the average particle is 138 nanometers. This size has not been classified as nano by some. For methods based on the concept of precipitation. Particle sizes of around 200-300 nm have now been achieved at the nanoscale (Boddu et al., 2008).

Table 5. Previous studies on MgO nanoparticles synthesis and characterization

Study /Samples	Method	Precipitant	MgO Purity (%)	size (nm)	Surface ara (m ² /g)	Pores diameter (nm)
(W. Wang et al., 2007)	Chemical Precipitation	Ammonia hydroxide/ PEG 400	-	15.34	-	-
(Boddu et al., 2008)	Precipitation	-	-	200	257	-
(Sreekanth et al., 2021)	Precipitation	Ammonia hydroxide	-	6.8 – 9.2	-	6.721
(Kalhori et al., 2017)	Presipitation	NaOH	-	-	76.12	-
(Alvionita, 2017)	Presipitation	NaOH/PEG 2000	66,6%	-	-	-

Depth discussion about the result of nano – MgO characteristics will describe based on Table 5. MgO nanoparticles synthesized in this study show promising characteristics, especially in terms of purity and adsorption capacity, which are often not reported in detail in previous studies. The sample synthesized with 0.5% NH₄OH, MgO purity of 87.1%, crystallite size of 11.691 nm, particle size of 138 nm, adsorption capacity of 243.0 mg/g, BET surface area of 43.429 m²/g, and pore diameter of 9.000 nm was obtained. Meanwhile, for the 1% NH₄OH sample, the purity of MgO was 83% and the crystallite size was 11.383 nm, with an adsorption capacity of 197.9 mg/g. A comparison with the study by Wang et al., (2007), which used ammonia hydroxide/PEG 400, reported a crystallite size of 15.34 nm, which is slightly larger than the crystallite size obtained in this study.

compared with other studies, there are significant variations in certain parameters. Boddu et al., (2008) reported a particle size of 200 nm and a much higher surface area of 257 m²/g, while Kalhori et al., (2017), who used NaOH, produced a surface area of 76.12 m²/g. On the other hand, Sreekanth et al., (2021) with ammonia hydroxide achieved a smaller crystallite size (6.8-9.2 nm) and a pore diameter of 6.721 nm. Alvionita, (2017) used NaOH/PEG 2000 and reported a MgO purity of 66.6%, which is lower than the synthesis results in this study. The advantage of the data presented lies in providing comprehensive information such as MgO purity and adsorption capacity.

Although the BET surface area of the nanoparticles synthesized in this study is relatively lower than those of Boddu et al. and Kalhori et al., the adsorption capacity obtained, especially 243.0 mg/g for the 0.5% NH₄OH sample, shows excellent performance. This indicates that there may be other factors besides the surface area, such as optimal pore size distribution or the presence of specific active sites, which play an important role in the adsorption efficiency. Overall, this study makes a valuable contribution with detailed data and shows the great potential of the synthesized MgO nanoparticles, particularly with 0.5% NH₄OH concentration, for adsorption applications.

3.5. Application of Nano-MgO for Improving Metals Bioavailability

The primary benefits of nanoparticles stem from their distinctive chemical and physical properties, with one notable application being the use of nano MgO to enhance the bioavailability of rare earth elements (REE) (García et al., 2004). Metal bioavailability is important parameter, expressing the level of metal that can be taken up by plants. Thus, bioavailability is a parameter of success for phytomining, one of the technologies applied to bioextract metals.

REE is found in red mud, a waste product of alumina processing from bauxite ore that contains high mineral content. One of REE that found in red mud is vanadium, as much as 0.205% weight red mud (Damayanti & Khaerunnisa, 2016). As vanadium is widely used in the battery industry for vanadium redox batteries (VRFBs) (Yuan et al., 2019), the application of nano MgO to red mud to increase the bioavailability of vanadium is

economically attractive. Experiments have been done to evaluate the capability of nano-MgO fabricated in this study to improve the bioavailability of V in the red mud. The result can be observed in Figure 6.

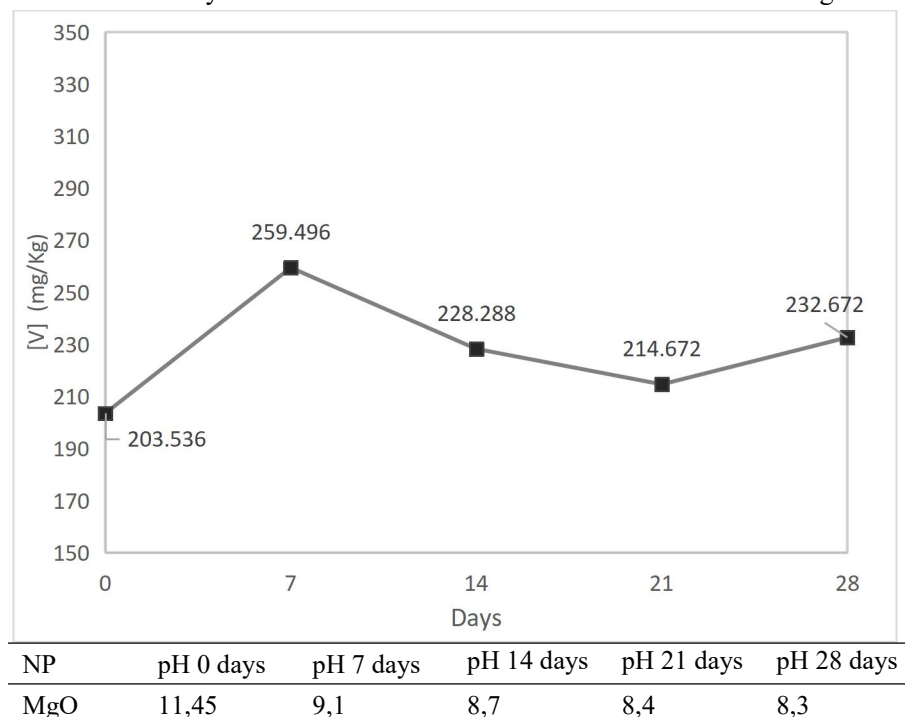


Figure 6. Fluctuation of vanadium bioavailability after nano MgO application in red mud

The fluctuation of vanadium metal bioavailability in the red mud is illustrated in Figure 6, with peak results occurring on the 7th day, at which point the value rose from 203.536 mg/kg to 259.496 mg/kg. This significant increase is due to several mechanisms, namely (i) the ability of nano MgO to maintain a pH in the range of 9-11 which is ideal for vanadium mobility, (ii) the physical bond between vanadium metal and mesopores on the nano MgO surface, and (iii) the occurrence of redox reactions that convert vanadium forms with low oxidation number (V(II), V(III)) into higher forms that are more bioavailable (V(IV), V(V)). The observed decline on day 7 is attributed to the suboptimal pH levels, the aging of the nanoparticles, and a weakening of the physical bond between the surface of nano MgO and vanadium metal.

Based on the description above, nano-MgO has a high potential to increase the bioavailability of vanadium metals. However, this process needs to be further optimized by conducting modification of the nanoparticles and the red mud media.

4. CONCLUSION

Nano MgO synthesized with MgCl_2 technical grade by precipitation method using 0.5% and 1% of NH_4OH as precipitant. Based on chemical composition, MgO concentration of Nano MgO using 0.5% NH_4OH and 1% NH_4OH is 87% and 83%, respectively. MgO phase dominant is periclase with purities 78.20% and 74.13% for NH_4OH 0.5% and NH_4OH 1% precipitant respectively. Average size crystallite of MgO with 0.5% NH_4OH and 1% NH_4OH precipitant is 11.691 nm and 11.383 nm respectively. The iodine number of Nano MgO using 0.5% NH_4OH and 1% NH_4OH is 193.97 mg/g and 243.01 mg/g. Thus, the optimum precipitator for nano MgO synthesized is using NH_4OH 0.5%. Surface analysis nano MgO is conducted to optimum variation, it is NH_4OH 0.5%. Surface area nano MgO using BET and Langmuir approach is 43.4298 m^2/g and 85.9954 m^2/g respectively. The material exhibits a nanoporous structure with an average pore diameter of 9.0002 nm and a significant pore volume (0.097719 cm^3/g for adsorption and 0.126 cm^3/g for desorption). indicating effective porosity for adsorption processes. An additional characterization to evaluate the performance of the nanoparticles was the increase of vanadium metal bioavailability in red mud up to 259.496 mg/kg on day 7 of application.

5. ACKNOWLEDGMENT

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