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The Effect of Hole Variation on The Performance of Catalytic Conventer from Pulp Waste with Zeolit X Catalyst from Rice Husk Ash

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ABSTRACT

The use of a catalytic converter in the exhaust is one solution to reduce pollutant levels in motor vehicle gas emissions. The catalytic converter was made using pulp waste and zeolite X from rice husk ash. This research examines the effect of varying number of holes 3, 5 and 7 on the absorption and conversion capacity of the catalytic converter. Making a catalytic converter from solid pulp waste consisting of grit, dreg and biosludge with the addition of zeolite synthesized from rice husk ash is carried out through the stages of granulating, mixing, molding and burning. The performance of the catalytic converter is measured using the Gas Analyzer shows that the catalytic converter with the 7 holes has the maximum absorption capacity for each motor vehicle gas emissions; CO, HC and CO_2 respectively amounted to 39.06; 33.18 and 44.80% with an increase in O_2 gas of 42.21%.

Keywords: catalytic conventer, pulp waste, zeolite X, number of holes, performance

1. INTRODUCTION

Pulp production by PT. Toba Pulp Lestari Tbk, which is located in Porsea, Tobasa Regency, North Sumatra Province, produces side products in the form of grit, dreg and biosludge solid waste around 7 tons/day. Accumulating solid pulp waste causes soil and air pollution which disturbs the surrounding community due to having to breathe bad smelling air every day. Therefore, efforts are needed to handle solid pulp waste. The results of the analysis of the chemical composition of grit, dreg and biosludge pulp solid waste show that it contains ceramic constituent materials such as clay ($Al_2O_3.2SiO_2.2H_2O$), feldspar ($KAlSi_3O_8.NaAlSi_3O_8.CaAl_2Si_2O_8$) and quartz ($SiO_2$) which allows pulp waste to be used as a manufacturing

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material. porous ceramic (conventer) which can absorbs and converts pollutants from motor vehicle gas emissions.[1]

Gas emissions from motor vehicle exhaust are the largest source of air pollution, reaching 60-70%, compared to industry which ranges from 10-15%. Meanwhile, the rest comes from households, burning rubbish, forest or field fires. Various pollutants emitted by motor vehicles include carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), carbon dioxide (CO_2), sulfur dioxide (SO_2), and lead (Pb) which have a negative impact on human health.[2,3,4] Carbon monoxide (CO) is one of the most common pollutants in motor vehicle gas emissions, which has earned the nickname the silent killer, a poisonous gas that is colorless, odorless and light but very dangerous.[5] When someone inhales CO gas, the body can experience decreased blood pressure, convulsions, loss of consciousness, and even coma.[6,7,8,9] If exposure is prolonged and the concentration of CO entering the body is high, it can cause decreased consciousness and even death, because this gas has the ability to bind to Hb (hemoglobin) in red blood cells. CO gas is able to replace oxygen in hemoglobin up to 200-250 times more strongly than oxygen which causes a decrease in the blood's ability to transport oxygen which the body really needs.[10,11,12]

One solution to reduce pollutant emissions from motorized vehicles is to use a device called a converter which can absorb and convert toxic compounds in exhaust gas into substances that are less toxic or not toxic at all. To increase the performance of the converter, a catalyst such as zeolite needs to be added. Zeolite is an aluminasilica compound that can be synthesized from natural materials and even waste containing silica such as rice husk ash. The author has successfully synthesized zeolite X from husk ash from 2015 until now through a hydrothermal reaction in an alkaline condition.[13] A catalytic converter is a converter that uses a catalytic media, where the media is expected to help or speed up the process of changing a substance (chemical reaction) so that gases such as CO can be oxidized to CO_2.[14]

The catalytic converter on the vehicle is installed in its position between the exhaust manifold and muffler. The catalytic converter has two functions, namely oxidizing unburned CO and HC gases to CO_2 and H_2O then reducing NOx to N_2 and O_2.[15,16] Sembiring reported that a converter with a porous ceramic filter derived from pulp waste was able to absorb CO from 49.5 to 21.18%, CO_2 from 18.87 to 11.33%, and HC from 84 ppm to 42 ppm while O_2 was resulting from 10.9 to 21.22% with a track distance of 6099 km.[1]

Research on making a catalytic converter from a mixture of pulp solid waste in the form of grit, dreg and biosludge with zeolite X as a catalyst synthesized from rice husk ash has been carried out through the stages of granulating, mixing, molding and burning. To obtain a catalytic converter with optimum performance capacity, in the manufacturing process variations in the addition of zeolite X to solid pulp waste are carried out in a ratio of 1:1; 1:2; and 1:3. Then variation the number of holes in the catalytic converter by 3, 5 and 7. The effect of the weight ratio of zeolite X and pulp waste on the performance of the catalytic converter has been published, where it was obtained that the catalytic converter with a zeolite X to pulp waste ratio of 1:2 had the most optimal absorption and conversion capacity. Therefore, in this article we specifically discuss the effect of the number of holes of 3, 5 and 7 on the performance of the catalytic converter.

Therefore, this research mainly aims to obtain a catalytic converter with a variety of holes that can be used as a motor vehicle exhaust gas converter. Specifically, this research aims to obtain information and data regarding how the number of holes can affect the working power of catalytic converters from pulp waste and zeolite X from rice husk ash as an absorber and converter of CO, HC and CO_2 gases.

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2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

The chemicals consist of rice husk ash, pulp solid waste, sodium hydroxide pellet (NaOH p.a (Merck), aluminium oxide anhydrous (Al_2O_3 p.a (Merck), Sodium Ethylene Diamine Tetra Acetate (Na_2EDTA p.a (Merck), aquabides (H_2O) (IKA) and distilled water (H_2O). Equipment consists of mortar and pestle, 200 mesh sieve, beaker, magnetic stirrer, clamp, spray bottle, Whatman number 42 filter paper, round bottom flask, Leibig cooler, magnetic stirrer hot plate, blender, oven, cylindrical stainless steel catalytic converter mold with a diameter of 6 cm and a height or length of 12 cm and a press as shown in Figure 1 below. The instruments used include Fourier Transform Infrared Spectroscopy (FTIR-8400 Shimadzu), X-ray Diffractometer (XRD Bruker D8 model) and Gas Analyzer (Qrotech QRO-401).

Figure 1. Catalytic converter mold and press

2.2. Research Procedure

2.2.1 Synthesis of Zeolite

The synthesis of zeolite was carried out by referring to the method used by Jahro and Kurniawan[17] with the optimum composition and conditions having been achieved. A total of 15 g of non-magnetic rice husk ash, 32 g of NaOH, 17.3 g of Al_2O_3 and 1 g of Na_2EDTA and 300 mL of aquabides were stirred in a 500 mL beaker using a magnetic stirrer hot plate at room temperature at a speed of 600 rpm for 10 hours. After the mixture is kept for about 12 hours. Then a hydrothermal process was carried out by refluxing the mixture successively at a temperature of 70 °C for 3 hours followed by a temperature of 120 °C for 8 hours. The synthesized solid is filtered and washed using distilled water until the pH of the water coming out of the filter paper is around 7. The synthesized solid is dried in an oven at 120 °C for 3 hours repeatedly until a constant weight is obtained. The synthesized solid was then characterized using infrared spectroscopy (FTIR) and X-ray diffraction (XRD).

2.2.2 Infrared Spectroscopic Measurements

To determine the framework structure of the synthesized zeolite, infrared spectroscopic measurements were carried out using Fourier Transform Infrared Spectroscopy (FTIR-8400 Shimadzu) in the wave number

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region of 300–4000 cm^{-1}. The infrared spectrum of the synthesized zeolite was compared to the infrared spectrum of standard zeolite X as a result of research by Flanigen et al.[18]

2.2.3 Powder X-ray Measurements

To determine the crystallinity and purity of the synthesized zeolite, powder X-ray diffraction measurements were then carried out using a Bruker D8 model diffractometer in the diffraction angle area (2θ): 4 – 40 degrees. The diffractogram of the synthesized zeolite was compared to the standard zeolite X diffractogram resulting from research by Ballmoos.[19]

2.2.4 Preparation of Pulp Solid Waste

Pulp solid waste (grit, dreg, biosludge) is cleaned from residual impurities resulting from paper processing, then dried in the sun and oven at 120 ºC. Solid waste pulp (grit, dreg, biosludge) that is clean and dry is ground using a grinder, sifted using a 200mesh sieve. Next, the grit, dreg, and biosludge which are in powder form are weighed and mixed evenly until homogeneous with a ratio of 1:1:1.

2.2.5 Catalytic Converter Manufacturing

Zeolite was added to the pulp solid waste mixture with a weight ratio of 1:2. The mixture is stirred while adding a certain amount of water until the mixture is homogeneous and easy to shape. Then the mixture is put into a catalytic converter mold and stored in the open air for 4 days until the catalytic converter can be removed from the mold. Next, the catalytic converter is burned or heated in a furnace at a temperature of 120°C for 10 hours. The resulting catalytic converter is characterized for its absorption and conversion power using a gas analyzer instrument.

2.2.6 Gas Analyzer Measurements

The catalytic converter is installed in the vehicle exhaust using an additional stainless pipe to ensure its stability during testing. Next, an exhaust gas detection sensor is inserted into the exhaust to take gas samples. Gases analyzed during testing include carbon monoxide (CO, % volume), hydrocarbons (HC, ppm volume), carbon dioxide (CO_2, % volume), and oxygen (O_2, % volume). The testing process for each catalytic converter product lasts 2 minutes, to ensure accurate and consistent data.

3. RESULTS AND DISCUSSION

3.1. Analysis of Characterization Results of Zeolite Synthesized from Rice Husk Ash

Characterization of the synthesized zeolite using infrared spectroscopy in the medium infrared region shows typical absorption of zeolite in four wave number regions: 440-540, 500-650, 750-820 and 1000-1120 cm^{-1} as shown in the infrared spectrum in Figure 2.

The presence of strong infrared absorption at a wave number of 1007.88 cm^{-1} marks the internal asymmetric stretching vibration of O-Si-O or O-Al-O from the zeolite X framework.[20] The infrared absorption at a wave number of 745.14 cm^{-1} indicates the existence of vibrations in the external symmetry range O-Si-O or O-Al-O. Meanwhile, absorption at wave number 440.70 cm^{-1} indicates bending vibrations of O-Si-O or O-Al-O and absorption at wave number 606.44 cm^{-1} indicates double ring vibration (D6R) which is characteristic of zeolite.[21] The presence of hydrated water in the synthesized zeolite. This is reinforced by the wide absorption at a wave number of 3457 cm^{-1} which indicates the presence of O-H stretching vibrations from water in the synthesized zeolite.[22]

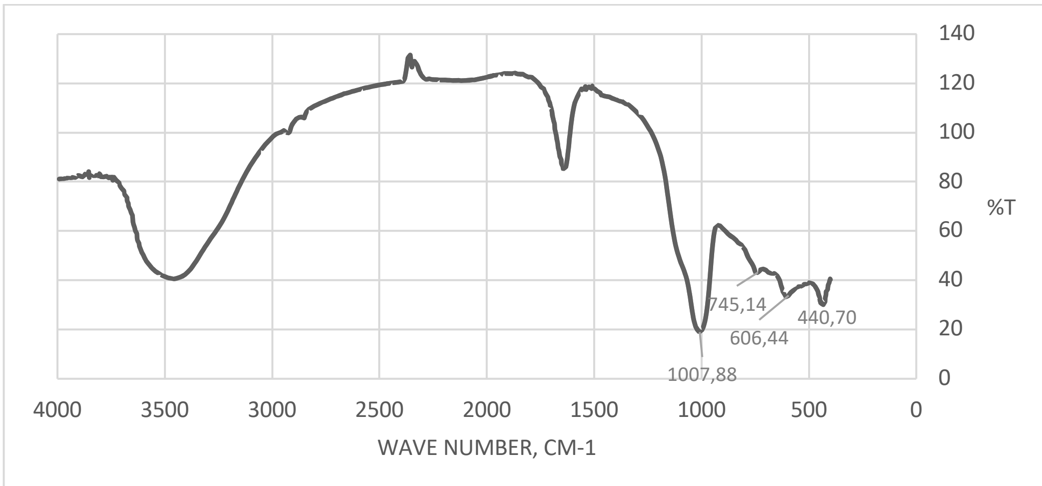

Figure 2. Infrared spectrum of zeolite X synthesized from rice husk ash[13]

To analyze the level of purity and crystallinity, the synthesized zeolite X was characterized using the X-ray powder diffraction method at 2 theta an angle of 0 – 50 degrees. The resulting diffractogram is shown in figure 3.

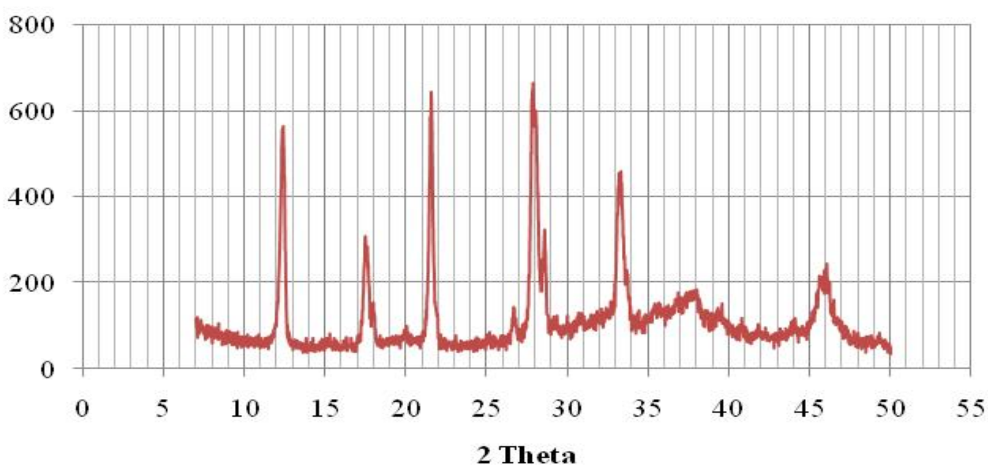

Figure 3. Diffractogram of zeolite X from rice husk ash[13]

The peaks diffraction which indicates the presence of X zeolite were shown at the diffraction angle (2θ): 12.34, 17.51, 21.53, 27.9, 28.5 and 33.22. The six diffraction peaks correspond to the main peaks of zeolite X. VonBalmoos[13] suggested that the crystal structure of zeolite X as shown by diffraction peaks at the following angles (2θ): 6.12; 10.00, 11.73, 15.43, 18.42, 20.07, 22.47, 23.31, 26.65, 29.21, 30.30, 30.94, 31.98, 33.59, 34.18 and 37.34°. Among these diffraction peaks, the peak that appears at an angle (2θ): 6.12, 10.00, 11.73, 15.43, 23.31, 26.65, 30.94, 31.98 and 33.59° are the main typical peaks of zeolite X which have relatively higher intensity than other peaks. X-zeolite synthesized from rice husk ash has six peaks which correspond to the typical peak of zeolite X according to Balmoos with the highest intensity at the diffraction peak of 27.9. This means that the zeolite synthesized by crystallinity is around 66.7%. But these zeolite solids can be estimated to have high purity levels which are indicated by the absence of diffraction peaks of other minerals and the diffraction peaks that appear to have high intensity and sharp.[13]

3.2. Analysis of Characterization Results of The Catalytic Converter

There are 3 catalytic converters produced from treatments varying the number of holes 3, 5 and 7 with a fixed weight ratio of zeolite to solid pulp waste, namely 1:2, as shown in Figure 4.

Figure 4. Catalytic converter with variations in the number of holes 3, 5 and 7

Each catalytic converter's performance was measured in the form of its absorption capacity for CO, HC and CO_2 gases, the results are summarized in Table 1.

Table 1: Absorption capacity of catalytic converters with a ratio of zeolite

Nu.	Catalytic converter with varying number of holes	Gas emissions			Gas absorbed (%)		
		CO (%)	HC (ppm)	CO_2 (%)	CO	HC	CO_2
1	3	0.50	161	9.3	21.87	25.81	25.60
2	5	0.47	156	7.8	26.56	28.11	37.60
3	7	0.39	145	6.9	39.06	33.18	44.80
	No catalytic converter	0.64	217	12.5	-	-	-

In table 1 it can be seen that the catalytic converter's absorption capacity for CO, HC and CO2 gas increases in line with the increase in the number of holes from 3 to 5 and from 5 to 7. This is because the number of holes is related to the surface area of the catalytic converter which can absorb and interacts with

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CO, HC and CO_2 gases so that the more holes there are, the greater the surface area of the catalytic converter, so the greater the opportunity for absorption and conversion reactions to occur for each gas.

The successful absorption and conversion of each gas is strengthened by the increase in oxygen gas levels contained in the exhaust gas because the zeolite hollow structure works quite effectively together with the pulp waste hollow structure in capturing CO, HC and CO_2 gases and then the zeolite active groups through dipole-dipole interactions (van der waals force) can maintain or bind each of these gases to remain in the cavity which then undergoes a change or conversion reaction which is estimated to take place as follows:[23]

Hydrocarbon gas conversion:

$C_xH_{4x(g)} + 2xO_{2(g)} \rightarrow xCO_{2(g)} + 2xH_2O_{(g)}$

Carbon monoxide gas conversion:

$2xCO_{(g)} + O_{2(g)} \rightarrow 2xCO_{2(g)}$

Nitrogen oxide decomposition reaction:

$2NO_{x(g)} \rightarrow N_{2(g)} + xO_{2(g)}$

Reaksi reduksi gas karbondioksida:

$xCO_{2(g)} \rightarrow xC_{(s)} + O_{2(g)}$

Data on the increase in oxygen in flue gas without and with the use of a catalytic converter with the varying number of holes are summarized in Table 2.

Table 2: Increase in oxygen gas in exhaust gas without and using a catalytic converter with the number of holes of 3, 5 and 7

Nu.	Catalytic converter with varying number of holes	O_2 emissions (ppm)	Increase in O_2 emissions (%)
1	3	17.35	32.44
2	5	18.53	41.45
3	7	18.63	42.21
	No catalytic converter	13.1	-

Increased O_2 levels contained in the exhaust gas using a catalytic converter with a number of holes of 7, which is 42.21% higher than that found in exhaust gas from a catalytic converter with a number of holes of 3 (32.44%) or 5 (41.45%). This is in accordance with the reduction in CO, HC and CO_2 gas levels in the exhaust gas, there is an increase in oxygen gas (O_2) levels which is thought to occur as a result of the decomposition reaction of nitrogen oxides and reduction of carbon dioxide gas.

4. CONCLUSION

Zeolite X was successfully synthesized from rice husk ash which functions as a catalyst in a catalytic converter from pulp waste. The ability of the catalytic converter to absorb and convert CO, HC and CO_2 gas is influenced by the ratio of zeolit X to pulp waste and the number of holes in the manufacturing process. A catalytic converter with a weight ratio of zeolite catalyst to pulp waste of 1:2 and a number of holes of 7 can reduce the CO, HC and CO_2 gas content and increase oxygen gas coming out of the exhaust gas to the highest compared to other catalytic converters.

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REFERENCES

1. Sembiring, A. D. (**2010**). *Pemanfaatan Limbah Padat Pulp untuk Bahan Baku Pembuatan Keramik Berpori yang Diaplikasikan sebagai Filter Gas Buang Kendaraan Bermotor dengan Bahan Bakar Premium*. Disertasi: Universitas Sumatera Utara
2. Aziz, A., & Bajwa, I. U. (**2007**). Minimizing human health effects of urban air pollution through quantification and control of motor vehicular carbon monoxide (CO) in Lahore. *Environmental monitoring and assessment*, 135, 459-464
3. Gasana, J., Dillikar, D., Mendy, A., Forno, E., & Vieira, E. R. (**2012**). Motor vehicle air pollution and asthma in children: a meta-analysis. *Environmental research*, 117, 36-45
4. Leroutier, M., & Quirion, P. (**2022**). Air pollution and CO2 from daily mobility: Who emits and Why Evidence from Paris. *Energy Economics*, 109, 105941
5. Saleh. (**2018**). *Keselamatan dan Kesehatan Kerja Kelautan: (Kajian Keselamatan dan Kesehatan Kerja Sektor Maritim)*. Yogyakarta: CV Budi Utama
6. Omaye, S. T. (**2002**). Metabolic modulation of carbon monoxide toxicity. *Toxicology*, 180(2), 139-150
7. Teksam, O., Gumus, P., Bayrakci, B., Erdogan, I., & Kale, G. (2010). Acute cardiac effects of carbon monoxide poisoning in children. *European Journal of Emergency Medicine*, 17(4), 192-196
8. Gozubuyuk, A. A., Dag, H., Kaçar, A., Karakurt, Y., & Arica, V. (**2017**). Epidemiology, pathophysiology, clinical evaluation, and treatment of carbon monoxide poisoning in child, infant, and fetus. *Northern clinics of Istanbul*, 4(1), 100
9. Vlisides, P. E., Mentz, G., Leis, A. M., Colquhoun, D., McBride, J., Naik, B. I., Mashour, G. A. (**2022**). Carbon Dioxide, Blood Pressure, and Perioperative Stroke: A Retrospective Case–Control Study. *Anesthesiology*, 137(4). 434-445
10. Sengkey, L., Sandri, Freddy, J., Steeni, W. (**2011**). Tingkat Pencemaran Udara CO Akibat Lalu Lintas dengan Model Prediksi Polusi Udara Skala Mikro. J*urnal Ilmiah Media Engineering*, 1(2)
11. Faradilla, A. R., Yulinawa, H., & Suswantoro, E. (**2016**, August). Pemanfaatan fly ash sebagai adsorben karbon monoksida dan karbon dioksida pada emisi kendaraan bermotor. *In Prosiding Seminar Nasional Cendekiawan* (pp. 2-1)
12. Rambing, V., Umboh, J. M., & Warouw, F. (**2022**). Literature Review: Gambaran Risiko Kesehatan pada Masyarakat akibat Paparan Gas Karbon Monoksida (CO). *KESMAS: Jurnal Kesehatan Masyarakat Universitas Sam Ratulangi*, 11(3)
13. Jahro, I. S., Nursanni, B., Nugraha, A. W., Juwitaningsih, T., Cindy, & Amalia, M. (**2024**). Synthesis of zeolite from rice husk ash through hydrothermal process in alkaline condition. *Indonesian Journal of Chemical Science and Technology (IJCST)*, 7(2), 153–161
14. Irawan, R. M. (**2003**). Unjuk Kerja Catalytic Converter Tembaga (Cu) Pada Saluran Gas Buang Kendaraan Bermotor Untuk Mereduksi Emisi Gas Carbon Monoksida. Disertasi: Universitas Diponegoro
15. Aalam, C.S., Saravanan, C.G., and Samath, C.M., (**2015**), *Reduction of Diesel Engine Emissions Using Catalytic Converter with Nano Aluminium Oxide Catalyst*, International Journal for Research in Emerging Science and Technology, 2(7):17-22
16. Mukherjee, A., Abdinejad, M., Mahapatra, S. S., & Ruidas, B. C. (**2023**). Metal sulfide-based nanomaterials for electrochemical CO2 reduction. *Journal of Materials Chemistry A*, 11, 9300-9332
17. Jahro, S.I., Kurniawan, R. (**2020**). Konventer katalitik dari limbah pulp dan abu sekam padi sebagai pengubah gas buang kendaraan bermotor. Seminar Nasional Kimia. Universitas Mulawarman. 30 Desember 2020

18. Flanigen, E.M., Khatami, H., Szimanski, H. A. (**1971**). Infrared structure studies of zeolite framework, molecular sieve zeolite-I. American Society Advances in Chemistry. 101, 201 – 229
19. Von Ballmoos, R. (**1984**). Collection of simulated XRD powder patterns for zeolites, Mobil Research and Development Corporation. Princenton. USA
20. Widayat, H., Satriadi, H., Cahyono, B., Setyo Tri Astuti, W.I., Febrianti, P. (**2019**). Synthesis of zeolite X molecular sieve from geothermal solid waste. Material Today: Proceedings. 13, 137 – 142
21. Bahri, S. (**20**15). Sintesis dan karakterisasi zeolit X dari abu vulkanik gunung Kelud dengan variasi rasio molar Si/Al menggunakan metode sol-gel, Skripsi, UIN Maulana Malik Ibrahim, Malang
22. Wang, C., Zhou, J., Wang, Y., Yang, M., Li, Y., Meng, C. (**2013**). Synthesis of zeolite X from low grade bauxite, Journal of Chmiecal technology and Biotechnology. 88(7), 1350 – 1357
23. Jahro, I.S., Nursani, B., Dewi, I., Amalia, M. and Cyndi. (**2024**). Optimization of Performance and Mechanical Properties Catalytic Converter from Pulp Waste and Rice Husk Ash as a Motor Vehicle Exhaust Gas Converter. Sciendo: Proceeding the 11th AISSTSE. Medan: Universitas Negeri Medan

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