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Research Journal of Industrial Pollution Prevention Technology

FOCUS AND SCOPE

Jurnal Riset Teknologi Pencegahan Pencemaran Industri (Research Journal of Industrial Pollution Prevention Technology) seeks to promote and disseminate original research as well as review, related to following area:

Environmental Technology : within the area of air pollution technology, wastewater treatment technology, and management of solid waste and harzardous toxic substance.

Process Technology and Simulation : technology and/or simulation in industrial production process aims to minimize waste and environmental degradation.

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PREFACE

Thanks to Allahu Robbie 'Alamin, Journal of Industrial Pollution Prevention Technology (JRTPPI) again will publish scientific articles, especially in the field of environmental technology for volume 13 no 2. Our high appreciation is directed to the authors and editorial board who have actively participated so as to maintain consistency of quality and punctuality of our periodic publications. We would like to acknowledge our high appreciation to the head of Center for Standardization and Industrial Pollution Prevention Services, Ministry of Industry.

This edition of the issue is five series published that in full-text English. This continous policy is an attempt of the editorial board to improve the author's performance in delivering the results of their researches. Articles in full-text English are more likely to be read by broader audience so that it will increase the number of citations. This policy is also applied in order to actualize our hope of being a globally indexed international journal.

The articles contained in this edition consist of studies concentration of carbon dioxide in urban areas, evaluation of implementation integrated biological system industrial wastewater treatment, studies mechanical and physical properties of geopolymer concrete, kinetic analysis of chicken eggshells and membrane against synthetic dye and analysis of potential utilization geothermal combined cycle residual in industrial. The five manuscripts accepted and published in this edition are from researcher and lecturer in Indonesia. The duration of submission, review, and editing of the manuscripts ranged from 1-6 months.

Hopefully, these scientific articles may be new source of knowledge and experience for readers from academic, researcher, industry, and society at large. We realize that nothing is perfect until the improvement of all parties involved is continuously done.

Semarang, November 2022

Chief Editor

Jurnal Riset

Teknologi Pencegahan Pencemaran Industri

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ABSTRACT

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Identifying Concentration of Carbon Dioxide at Heights of 1.5 M and 15 M in Six Locations in Urban Areas

Several activities in urban areas emit CO_2 gas and the amount of the emission is closely related to land use. This will, in turn, increase global warming phenomena in urban areas. So far, the estimation of pollutant concentrations in the ambient air has been carried out at the height of human breath, and very rarely the concentration values at low-level altitudes have been studied in Indonesia. This study tries to analyze the CO_2 concentration based on different altitudes and different locations.

Measurements of this study were carried out in industrial, residential, commercial, and highway areas using drones at two altitudes of 1.5 m and 15 m. The use of altitude variations to know the homogeneity of CO_2 spatial distribution at different heights. The results of the study showed CO_2 concentrations on weekday mornings and afternoons, and weekend mornings in the sampling areas at 1.5 m and 15 m in the range of 393 – 462 ppm and 391 – 460 ppm, respectively. The statistical test showed that there is no significant CO_2 concentration difference between altitudes of 1.5 m and 15 m, with only a 0.17% difference value on average. The Tugu Industrial Estate area has the highest concentration of CO_2, while the area on Jalan Perintis Kemerdekaan has the lowest concentration.

(Author)

Keywords: Carbon Dioxide, Commercial, Housing, Industrial Estate, Unmanned Aerial Vehicles

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Evaluation of the Implementation Integrated Biological System Industrial Wastewater Treatment Plant: Pollutant Removal, Operational Maintenance, Estimation of Carbon Emission

The development of WWTP in business activities needs to pay attention to getting appropriate WWTP that is more valuable to support sustainable development. This study aims to evaluate two systems of integrated biological WWTP; anaerobic-wetland, and anaerobic-aerobic-wetland, including the effectiveness of pollutant removal, operational and maintenance, and estimation of carbon emissions. The performance of pollutant removal was evaluated by analyzing inlet and outlet samples of WWTP. An operational and maintenance evaluation was carried out by studying the WWTP operating system and maintenance procedures supported by a literature review. Carbon emission estimation was carried out using a formula referring to the IPCC Guidelines (2006). Organic matter removal of anaerobic-aerobic-wetland WWTP in the form of BOD_5 and COD are 92.12% and 91.72%, respectively, higher than anaerobic-wetland WWTP are 88.69% of BOD_5 and 77.62% of COD. Anaerobic-aerobic-wetland WWTP needs more maintenance and operation than anaerobic-wetland WWTP. The highest carbon emission of both WWTP is 41530.91 $kgCO_2$ eq/year of anaerobic-wetland WWTP from the organic matter removal process and 46485.15 $kgCO_2$ eq/year of anaerobic-aerobic-wetland WWTP. Electrical energy consumption emits in anaerobic-aerobic-wetland WWTP is 22338 $kgCO_2$ eq/year higher than anaerobic-wetland WWTP at 4299.70 $kgCO_2$ eq/year. Total carbon emissions of anaerobic-wetland WWTP is 47404.58 $kgCO_2$ eq/year and anaerobic-aerobic-wetland WWTP is 68900.23 $kgCO_2$ eq/year.

(Author)

Keywords: Carbon emission, Integrated biological system, Pollutant removal, WWTP evaluation

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The Effect of Bentonite and Palm Shell Ash on The Mechanical and Physical Properties of Geopolymer Concrete

Geopolymer concrete is an alternative to obtaining environmentally friendly mortar by synthesizing materials that contain a lot of aluminum silicate. This study aims to determine the effect of bentonite and palm shell ash composition on geopolymers' physical and mechanical characteristics. All materials are mashed, mixed, and molded with a 5x5x5 cm^3 cube. Ten specimens were prepared with bentonite - palm shell ash compositions are 40/45, 45/40, 50/35, 55/30, and 60/25 wt%. Meanwhile, the composition of NaOH, Na$_2$SiO$_3$, superplasticizer and water remained at 1.3, 7.7, 2, and 5 wt%, respectively. Then the samples were dried at room temperature for 24 hrs and heated at 60 °C or 80 °C for 12 hrs. The geopolymer concrete with the best characteristics was obtained with a composition of 40 wt% bentonites and 45 wt% palm shell ash by heating at 80 °C. This specimen has a compressive strength of 11.94 MPa with a density of 2.42 g/cm^3, porosity of 8.43%, and absorption of 3.48%. The results have a chemical composition of 55.59% SiO$_2$, 9.45% Al$_2$O$_3$, and 8.22 Fe$_2$O$_3$ with a dominant quartz phase. Scanning electron microscope photo shows good bonding between particles, and there are no pores formed.

(Author)
Keywords: Bentonite, Concrete, Compressive Strength, Geopolymer, Palm Shell Ash

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The Kinetic Analysis and Adsorption Isotherm of Chicken Egg Shells and Membranes Against Synthetic Dyes

Textile industry waste at this time is enough to worry the community and the environment. The presence of synthetic dyes in water is hazardous, even in small concentrations. These synthetic dyes are derivatives of aromatic compounds such as benzene, toluene, and naphthalene, which are more resistant and stable than natural dyes. The adsorption method is used because it is easier to do, has no side effects, and does not require complicated and expensive equipment. In this study, the shells and membranes of discarded chicken eggs became useful as an absorbent of indigo carmine dye with an adsorption capacity of 6.399 mg/g. The adsorption reaction kinetics were analyzed from the optimal contact time data, and the reaction isotherm was analyzed from the adsorption optimal concentration data. The kinetic model that fits the research is the second pseudo-order with R^2 = 0.9998. The adsorption mechanism demonstrates that the adsorption capacity is proportional to the adsorbent's active sites. The adsorption isotherm model, with R^2 = 0.9748, is more closely related to the Freundlich isotherm model, indicating that adsorption occurs in several layers. From an economic point of view, chicken egg shells and membranes can be recommended as dye absorbers that are eco-friendly, efficient, and simple to obtain while lowering organic solid waste.

(Author)
Keywords: Adsorption, Dyes, Indigo Carmine, Isotherm, Reaction Kinetics

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Analysis of Potential Utilization of Sarulla Geothermal Combined Cycle Residual Fluids for Direct Use in The Coffee Industry

The Geothermal Power Plant is one of the new renewable energy power plants. In Indonesia, the realization has reached 2%. Sarulla Operations Limited is the first geothermal power plant in Indonesia, located in North Tapanuli Regency, that utilizes combined cycle technology. Coffee is the leading commodity in the North Tapanuli district, with a plant area of 17,586 hectares. Coffee is dried in the traditional way (open field drying) so that it is still constrained by rain and cloudiness and can only be done during the day. The reinjection well fluid has a temperature of 103°C with a flow rate of 4978 t/h and a pressure of 6–14 Bar. This study analyses the residual fluid energy for coffee drying purposes. Energy and exergy calculations are done manually and using DWSIM software with a total of 24 data points 24 hours a day to represent the availability of dryers both day and night. The results showed that the most energy needed to raise the drying air temperature at night from 15°C to 60°C was 125.62 kW, while the lowest energy needed to raise the drying air temperature during the day from 30°C to 40°C was 27.92 kW. The results of research calculations show the energy potential for residual fluid from geothermal plants to be used for drying coffee for 24 hours, both day and night.

(Author)
Keywords: Coffee, Direct Use, Geothermal, Residual Fluids, Sarulla

The Effect of Bentonite and Palm Shell Ash on The Mechanical and Physical Properties of Geopolymer Concrete

Muhammad Amin*[1], Yugo Chambioso[2], Suharto[1], Roniyus Marjunus[2], Yusup Hendronursito[1]

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ABSTRACT

Geopolymer concrete is an alternative to obtaining environmentally friendly mortar by synthesizing materials that contain a lot of aluminum silicate. This study aims to determine the effect of bentonite and palm shell ash composition on geopolymers' physical and mechanical characteristics. All materials are mashed, mixed, and molded with a 5x5x5 cm^3 cube. Ten specimens were prepared with bentonite - palm shell ash compositions are 40/45, 45/40, 50/35, 55/30, and 60/25 wt%. Meanwhile, the composition of NaOH, Na$_2$SiO$_3$, superplasticizer and water remained at 1.3, 7.7, 2, and 5 wt%, respectively. Then the samples were dried at room temperature for 24 hrs and heated at 60 °C or 80 °C for 12 hrs. The geopolymer concrete with the best characteristics was obtained with a composition of 40 wt% bentonites and 45 wt% palm shell ash by heating at 80 °C. This specimen has a compressive strength of 11.94 MPa with a density of 2.42 g/cm^3, porosity of 8.43%, and absorption of 3.48%. The results have a chemical composition of 55.59% SiO$_2$, 9.45% Al$_2$O$_3$, and 8.22 Fe$_2$O$_3$ with a dominant quartz phase. Scanning electron microscope photo shows good bonding between particles, and there are no pores formed.

1. INTRODUCTION

Ordinary Portland cement-based mortar is now the most used building material in the world. The annual use of cement reaches 4 billion tons with an annual growth rate of 4% (Mineral Commodities Summary, 2014). However, Portland cement production requires much energy and produces CO$_2$ gas that pollutes the environment (Pavithra, 2016). Generally, for every tonne of Portland cement production, one tonne of CO$_2$ is released into the atmosphere (Davidovits, 1994). Under these conditions, geopolymer concrete is one of the best options to reduce global warming. It can minimize CO$_2$ emissions by up to 80% (Pavithra, 2016).

Geopolymers are the latest innovation in concrete manufacturing worldwide. The conventional Portland cement is completely replaced with an aluminosilicate material activated by a strongly alkaline solution as a binder. (Patankar et al., 2013). Metakaolin, fly ash, red mud, agricultural waste, and mine waste are natural and industrial products used to make geopolymer binders (Slaty et al., 2013). Silica-rich materials such as fly ash, slag, rice husks, and aluminum-rich materials such as clays, including kaolin and bentonite, are significant parts of polymerization development (Part et al., 2015).

Palm shell ash is a pozzolanic material which is not bound like cement but contains dominant SiO$_2$ (Graille et al., 1985). Palm shell ash is obtained from a steam power

plant that uses palm kernel shells as fuel at temperatures from 800 - 1,000°C (Tangchirapat, 2009). Palm shell ash includes a large amount of silica dioxide and can be used as an alternative to cement. Palm shell ash is one of the pozzolanic materials found in most of the world. Palm shell ash can be used effectively to reduce cement use and waste volume, which is suitable for preserving the environment (Tangchirapat, 2009).

Some researchers used palm shell ash for an experiment. Production of geopolymer concrete using a mixture of fly ash and palm ash was well done by Islami et al. (2012). The highest compressive strength value occurs at the ratio of fly ash and palm ash 75:25, which is 20 MPa heated at a temperature of 110 °C. A higher compressive strength of geopolymer concrete can produce by mixed of ash from agro-industrial waste. The 25 MPa compressive strength was achieved from the 70:30 composition of fly ash and palm ash (Ariffin et al., 2017). Another experiment resulted from 44.57 MPa of geopolymer concrete compressive strength. This higher geopolymer compressive strength is produced from blast furnace slag and palm ash with a ratio of 0.2 (Yusuf, 2014).

Based on the previous studies, this research was conducted to see the effect of bentonite and palm shell ash on geopolymer cement's mechanical and physical properties.

2. METHODS

The parameters used for the design of the experiment are shown in Table 1. Palm shell ash is obtained from the fuel combustion process in a palm oil factory.

Bentonite and palm shell ash were sieved on 100 mesh. Admixture of superplasticizer SP 200, NaOH (Merck), Na_2SiO_3 (Rofa, 58%), and water were added to the slurry according to the composition in Table 1. All materials are mixed and molded at 5x5x5 cm^3 cubes. The specimens are allowed to stand for 24 hrs and then heated in the oven at 60 °C and 80 °C for 12 hrs.

The geopolymer concrete was characterized by compressive strength, density, porosity, and absorption test. The compressive strength test was carried used the universal testing machine model HT-2402. The chemical content was analyzed by X-ray fluorescence using Malvern Panalytical Epsilon 3 and crystal phase by x-ray diffraction using Panalytical X'Pert 3 Powder. The topography of geopolymer was obtained by SEM Phenom Pro X.

3. RESULT AND DISCUSSION

XRF characterization was carried out to determine the chemical content used to manufacture geopolymer mortar. Bentonite with high Al_2O_3 content helps form bonds between concrete particles. While the dominant palm shell ash is silica, which is 51.47%. The chemical content of bentonite and palm shell ash overall can be shown in Table 2.

Based on Table 3 shows that the sample was heated at 80 °C and 60 °C, dominated by SiO_2, Al_2O_3, and Fe_2O_3 compounds. The results of the characterization of these samples follow XRF analysis of bentonite and palm shell ash raw materials, where the results of the analysis are dominated by SiO_2, Al_2O_3, and Fe_2O_3 compounds.

Table 1. Composition of geopolymer cement manufacture

Specimen	Bentonite (%)	Palm shell ash (%)	NaOH (%)	Na_2SiO_3 (%)	Superplasticizer (%)	Water (%)
I	40	45	1.3	7.7	2	5
II	45	40	1.3	7.7	2	5
III	50	35	1.3	7.7	2	5
IV	55	30	1.3	7.7	2	5
V	60	25	1.3	7.7	2	5

Table 2. Chemical composition of raw material

Compound	Bentonite (%)	Palm shell ash (%)
SiO_2	65.20	51.47
Al_2O_3	18.10	2.00
Fe_2O_3	9.41	4.50
K_2O	0.99	15.17
TiO_2	0.33	0.39
CaO	2.79	18.36
P_2O_5	0.12	5.09
NiO	0.09	-
SO_3	0.15	-
MnO	2.94	0.37
MgO	-	2.26

Table 3. Chemical composition of geopolymer

Compound	Composition (%, wt)	
	80 ℃	60 ℃
SiO_2	55.59	58.54
Fe_2O_3	8.22	9.43
Al_2O_3	9.45	11.73
CaO	13.10	9.74
K2O	7.74	5.51
TiO_2	0.53	0.51
MnO	0.44	0.30
P_2O_5	2.90	2.43
MgO	1.42	1.18

Based on Figure 1, the density values decreased due to increasing the ratio value. It has happened at temperatures of 60 °C and °80 C. The confidence level of the trend formed on this graph is 98% for temperatures 60 °C and 96% for 90 °C. The polymerization process is similar when heated at 60 °C to 90 °C. The temperature is close to perfect, and fast polymerization process (Duxson et al., 2007). However, the higher the temperature, the higher the evaporation process. A temperature of 80 °C causes a higher shrinkage of water content than a temperature of 60 °C, so the density is slightly different between these two temperatures. The density value is related to the porosity value. The higher the density, the smaller of concrete

porosity. It creates higher compressive strength of the mortar (Malau, 2014).

Based on Figure 2, the porosity value is directly proportional to the ratio of bentonite ash. The confidence level of the trend formed on this graph is 95% for temperatures 60 °C and 91% for °80 C. The porosity value was closely related to the density value. This is because when the water in the geopolymer mortar evaporates, the pores that were previously filled with water become empty, and when the heating temperature is higher, the geopolymer mortar will dry out and form a tight bond and close the empty hole, causing the mortar to become denser. Therefore, the increased curing temperature used in geopolymer mortar will decrease the porosity value (Amin & Suharto, 2017).

Based on Figure 3, the absorption value is directly proportional to the temperature. The confidence level of the trend formed on this graph is 98% for temperatures 60 °C and 95% for 80 °C. The large pores in the geopolymer mortar, the more cavities are made. The empty cavity can absorb much water. High temperature caused less water to absorb in the geopolymer concrete (Amin & Suharto, 2017). In addition, the higher the heating temperature, the less the geopolymer mortar will absorb water. In other words, the smaller the absorption (Amin & Suharto, 2017). The low absorption value makes a low water absorption rate in the mortar. It is made higher the density value and compressive strength, and the mortar structure is getting tighter.

Based on Figure 4, the compressive strength value is directly proportional to temperatures. The density value obtained was high because the resulting mortar structure is dense. In addition, the compressive strength value is related to the porosity value and absorption value. If the compressive strength value is high, the porosity and absorption value will be smaller. The water granules in the geopolymer mortar will evaporate due to the use of high heating temperatures. Water evaporation is formed in smaller porosity in the mortar and increases the compressive strength value of the mortar.
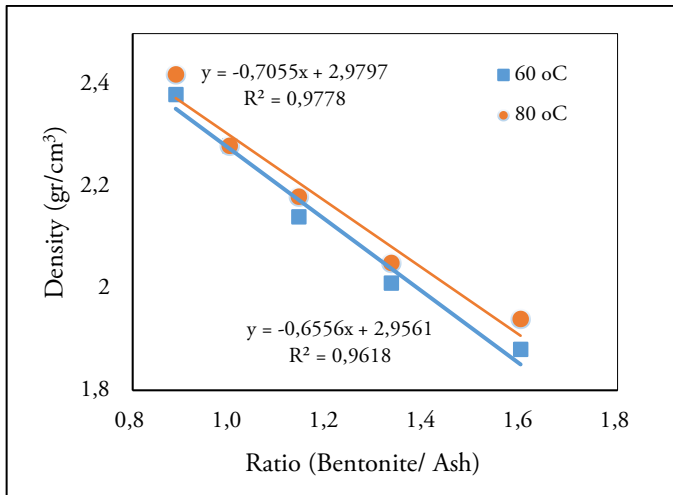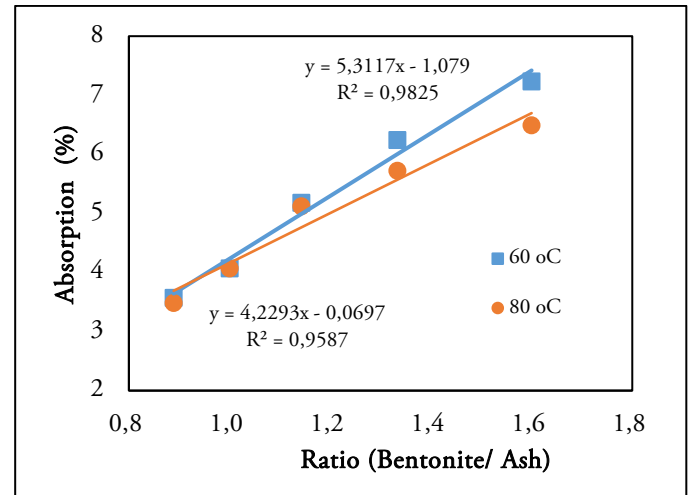
Figure 1. The graph of density vs ratio

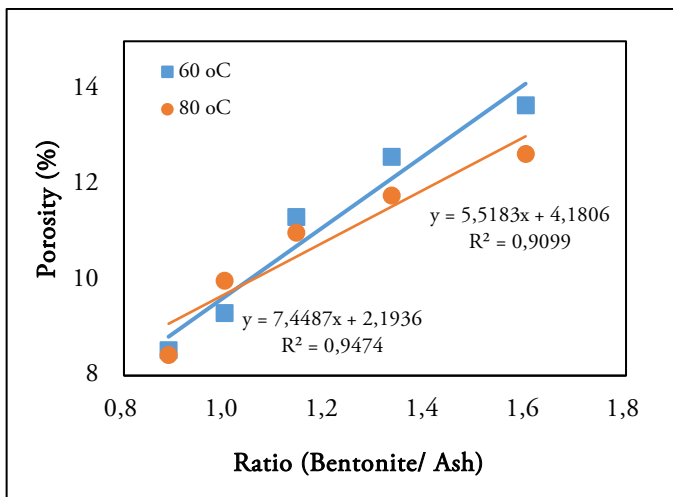**Figure 3.** The graphic of absorption vs ratio

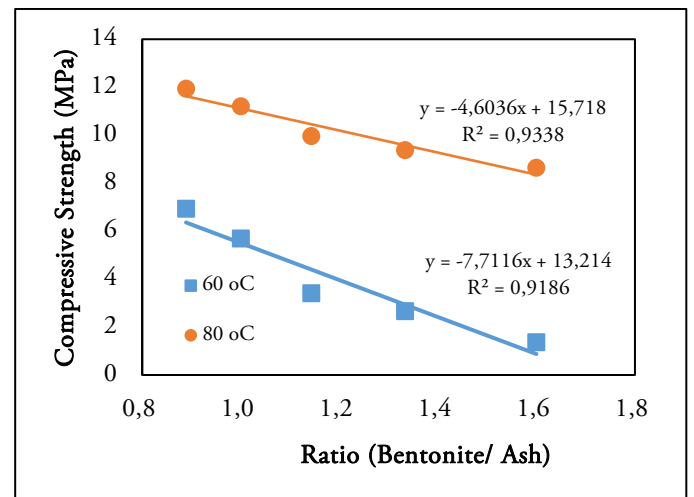**Figure 2.** The graphic of porosity (P) vs ratio

Figure 4. The graphic of compressive strength vs ratio

Geopolymer concrete made using geopolymer will bind with high alkaline NaOH to form a polysilicon-aluminate gel. It will harden due to the crystallization process and will increase the compressive strength of the mortar (Amin & Suharto, 2017). The increase in the percentage of bentonite causes a decrease in the compressive strength value due to an increase in porosity and changes in the microstructure. The addition of bentonite to the geopolymer increases the number of pores and pore size and widens the pore size distribution because bentonite contains much water (Yang et al., 2020).

XRD characterization was performed on samples with the highest compressive strength value (80 °C). The results of the X-Ray Diffraction test show that the higher the intensity, the higher the crystallinity level (Latif et al., 2014). The crystal phases formed are quartz. The crystal structure is hexagonal and is the highest peak on the chart, with its highest intensity at 2θ= 26.654°, as evidenced by the ICDD result 01-085-0795. Subsequently formed a sillimanite phase (Al_2SiO_4) with an orthorhombic crystal structure, its highest intensity at 2θ= 27.584°. The sillimanite phase showed conformity with the ICDD reference 01-089-0888. In the anorthite phase ($Ca(Al_2Si_2O_8)$) with the anorthic crystalline structure, its highest intensity at 2θ= 31.310°, the anorthite phase shows conformity with the ICDD reference 01-089-1460. In addition to the quartz, sillimanite and anorthite phases are formed, namely magnetite (Fe_3O_4) with an orthorhombic

crystal structure, the highest intensity of which is at the position of $2\theta= 19.791°$ with ICDD reference 01-076-0958. The intermediate microcline phase ($KAlSi_3O_8$) at position $2\theta= 36.646°$ with an anorthic crystalline structure.

The dominant phase formed is a quartz mineral group with the chemical formula silicon oxide (SiO_2), which indicates that the mortar has a lot of SiO_2, so it acts as a filler that fills the pores of the mortar and causes the mortar to have the highest compressive strength. The results are under the sample XRF test, where the compound produced is dominated by SiO_2.

X-ray diffraction analysis for two specimens has higher and lower compressive strength values. From the results of the XRD diffractogram obtained from the XRD analysis carried out in the study, the analysis is qualitative research, where the low peak does not indicate the number of crystals contained in the sample (Jefry, 2019). XRD analysis of specimen one at a temperature of 80 °C is shown in Figure 5.
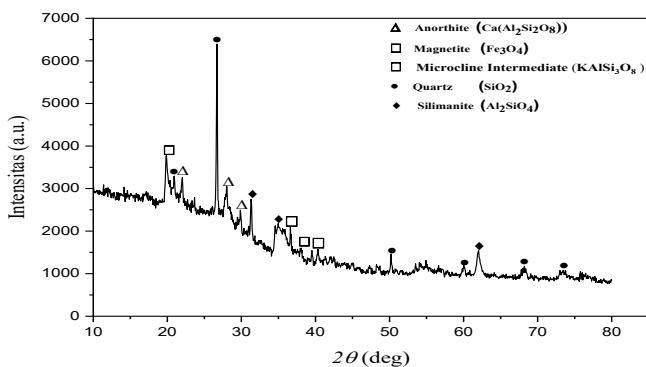

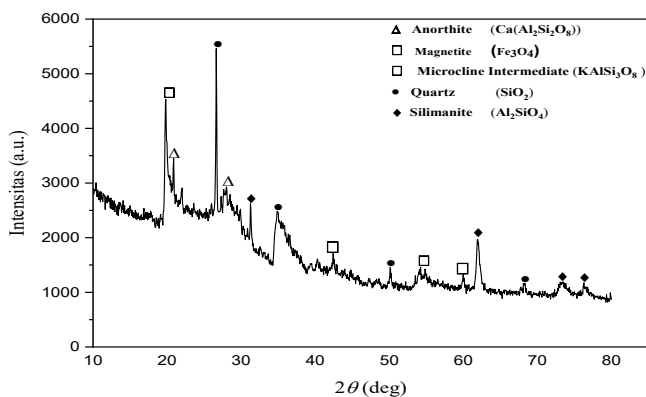**Figure 5.** X-ray diffraction of temperature at 80 °C

Figure 6. X-ray diffraction of temperature at 60 °C

XRD characterization was carried out on samples with the lowest compressive strength value (composition V at 60 °C). The results of the X-Ray Diffraction test show that the higher intensity, the higher the crystallinity level (Latif et al., 2014). The crystal phases formed are quartz. The crystal structure is hexagonal and is the highest peak on the chart, with its highest intensity at $2\theta= 26,644°$, as evidenced by the ICDD result 01-085-0504. Subsequently formed a sillimanite phase (Al_2SiO_4) with an orthorhombic crystal structure, its highest intensity at $2\theta= 27,584°$. The sillimanite phase showed conformity with the ICDD reference 01-089-0888. The anorthite phase ($Ca(Al_2Si_2O_8)$) with the anorthic crystalline structure, its highest intensity at $2\theta= 27,836°$, the anorthite phase shows conformity with the ICDD reference 01-089-1461. In addition to the quartz, sillimanite and anorthite phases are formed, namely magnetite (Fe_3O_4) with an orthorhombic crystal structure, the highest intensity of which is at the position of $2\theta= 19,791°$ with ICDD reference 01-076-0958. And the intermediate microcline phase ($KAlSi_3O_8$) at position $2\theta= 42,423°$ with an anorthic crystalline structure.

The dominant phase formed is a quartz mineral group with the chemical formula silicon oxide (SiO_2). The results are under the sample XRF test, where the compound produced is dominated by SiO_2.

The results of the XRD diffractogram obtained from the XRD analysis have been carried out in the study. The analysis is qualitative research, where the low peak does not indicate the number of crystals in the sample (Jefry, 2019). XRD analysis of specimen 5 at 80 °C is shown in Figure 6.

Figure 7 depicts the morphology of the particle size SEM with a magnification of 2000X. The surface does not produce many pores (Jiminez et al., 2004). The distribution of constituent elements has a distribution of dominant elements in the form of Si, Al, and Fe.

The results of the EDS analysis are shown in Figure 8 where in the spectrum 0-2 KeV contains elements of carbon (C), oxygen (O), potassium (P), potassium (K), magnesium (Mg), aluminum (Al) and silicon (Si). In the energy spectrum of 2-4 KeV, there are elements of

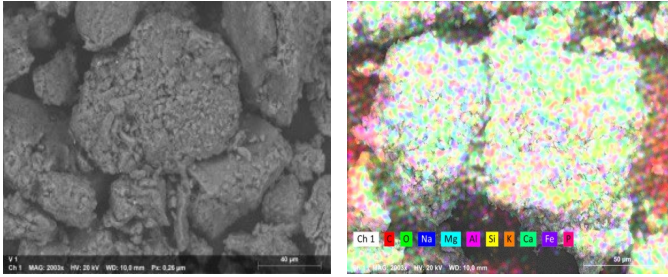potassium (K) and calcium (Ca), and in the energy spectrum of 4-7 KeV, there are elements of iron (Fe).

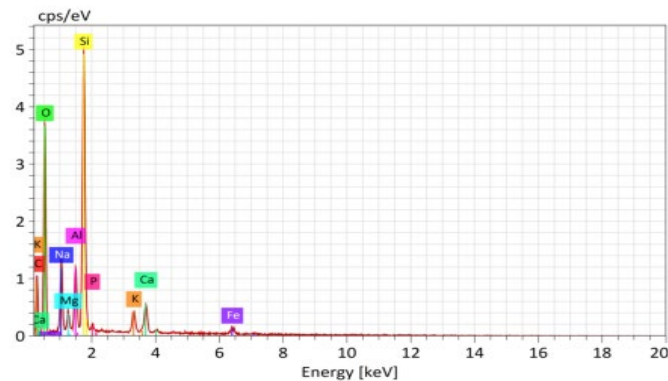**Figure 7.** Micro photo of SEM for specimen 1 (temperature 80 ℃)

Figure 8. The result of EDS for specimen 1 (the temperature at 80 ℃)

4. CONCLUSION

The high palm shell ash content and higher temperature increase the geopolymer compressive strength. This higher strength only used small content of bentonite. The best value obtained of 11.94 MPa with a density of 2.42 g/cm^3, porosity of 8.43%, and absorption of 3.48%. The chemical contained 55.59% SiO_2, 9.45% Al_2O_3, and 8.22% Fe_2O_3, with the phases formed in the form of quartz, sillimanite, anorthite, magnetite, and microcline intermediate. SEM results show that the surface does not produce many pores, so it has the highest compressive strength value. The lowest compressive strength value was obtained from the specimen with low content of palm shell ash. The low compressive strength was 6.94 MPa, with porosity and absorption value were 13.66% and 7.23%, respectively. The chemical contains 58.54% SiO_2, 11.73% Al_2O_3, and 9.43 Fe_2O_3, with the phases formed not different from the high compressive strength specimen. The SEM results show that the surface has many pores, so it has the

lowest compressive strength value. This research shows that bentonite and palm shell ash waste is feasible and can be used in geopolymer cement manufacture.

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