

Study of Desiccant Rice Husk Ash for Air Conditioning System

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Study of Desiccant Rice Husk Ash for Air Conditioning System

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1. Introduction

Indonesia is one of the producers and consumers of paddy or rice due to more than 95% of the Indonesian population uses rice as staple food. The by-product of paddy to rice, is hush or rice hush. Indonesia's dry paddy production in 2018 was estimated around 82 million tons. Rice mills produce 72% of paddy, 5-8% of bran, and 20-22% of rice husk. If the content of Hush is 20%, then rice production produces around 16.4 million tons per year. So far, rice husk is a by-product of agriculture. If there is no use, it can become soil pollution. Up until now in Indonesia, it is widely used as animal feed, fertilizer, mushroom planting media and fuel for making bricks, tiles and others.

Today there has been a lot of research that has been done about the usage of rice husk as an economical raw material in making silica. Because manufacturing silica from quartz sand, may causes damage to the environment as well as global warming effect. The melting of quartz sand into sodium carbonate requires a furnace temperature of 1300 °C [1].

SDC cooling system (Solid Desiccant Cooling), is one type of AC machine that uses silica gel as a natural active ingredient in energy and mass conversion in cooling systems. The advantages of *SDC* silica gel compared to silica gel from quartz sand are: (1) Increase the usefulness of rice husk, (2) The process of making silica gel will be more economical, (3) Reducing global warming and soil pollution,



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(4) Raw materials are abundant, and (5) Some treatments to rice hush in the process of making silica gel, may improve product quality.

The adsorption / desorption phenomenon was discovered more than two centuries ago by C. W. Scheele in 1773 and by F. Fontana in 1777. In 1785, they discovered that when they heat the charcoal contained in the test tube the gas is decomposed. The gas is then adsorbed again when the charcoal is cooled [2]. Adsorption is classified into (1) physical adsorption, where attraction that occurs between the adsorbate molecule and the porous surface of the material, this is the Vander Waal style. In physical adsorption there is a weak pull between vapor or gas and the surface of the porous material, then the type of adsorption can be easily reversed ie reversible; and chemical adsorption, where attraction between steam or gas and the surface of a porous material has the same strength as a chemical bond, this type of adsorption is called chemical adsorption. In chemisorption, the attraction is so strong that chemisorption adsorption cannot be easily irreversible [3,4].

Adsorption isotherms measured on various gas-solid systems have various forms, and can be grouped into one of six types according to the International Union of Pure Applied Chemistry (IUPAC) Classification 1994 [5] with the majority produced from physisorption, Fig. 1 showing six types of isotherms, which only apply to the adsorption of a single component gas in a condensable range, and are very useful for studying porous materials.

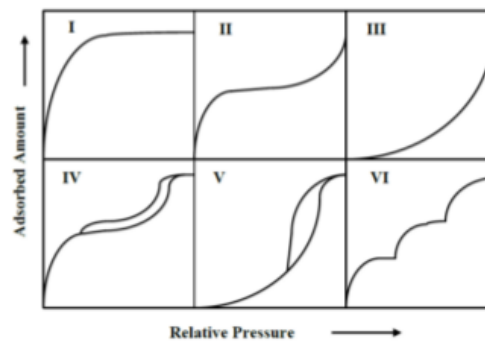


Figure 1. Six types of isotherms, based on the IUPAC classification standard [6]

Type I represents a highly hydrophilic material with a steep increase in gas absorption at very low relative pressure (P / P_o). Substances with type II or IV isothermic forms are also classified as hydrophilic materials. For these materials, the water adsorption capacity is very high measured at low and medium P / P_o . In addition, hydrophilic materials include those which exhibit unusual type-like isothermic types. In contrast, materials with type III isotherms are recognized as hydrophobic or low hydrophilic, indicating low water adsorption at low P / P_o and a sudden increase in water adsorption at high P / P_o . Similar to type III isotherm, type V isotherm also shows low water adsorption at low P / P_o . However, the sigmoidal or S-shape curve on medium or high P / P_o is studied further, this shows an increase in sudden water absorption between narrow P / P_o . The optimum desiccant for the SDC system must be like type V isotherm. This is because materials that have type I, II or IV isotherms are more difficult to regenerate because they are more hydrophilic and have a higher amount of water adsorption at low P / P_o . In addition, water adsorption occurs in P / P_o which is too high for material that has type III isotherm [7]. Within the SDC system, the active material desiccant is a material that has properties, capable of absorbing as much water vapor as possible by adsorption, if it is in the air flow containing water vapor and is able to release absorbed water vapor (desorption) if it is in the womb low water vapor. Thus desiccant has properties as a material capable of alternating adsorption and desorption (regeneration) of steam, which is ideally reversible. The characteristic parameters of a solid desiccant material can be concluded are (1) Chart of adsorption / desorption, (2) The main dimensions of the desiccant pore, and (3) Composition of desiccant compounds. This diagram is also

known as the isotherm diagram. From sub-chapter of types of adsorption isotherm, the types have been explained. For solid desiccants that have good adsorption / desorption characteristics are types II, III and IV. For type I the adsorption power is very good but the desorption is very low.

The adsorption / desorption characteristics can be known easily using the Vapor Sorption Analyzer (VSA) or Gas Sorption Analyser (GSA). VSA is very suitable to be used for the analysis of moisture adsorption / desorption properties in solid materials. While GSA generally applies to know the characteristics of adsorption / desorption of various kinds of gases on various adsorbent media. The main difference between the two types lies in the adsorbent media. DVS uses steam + nitrogen gas as an adsorbent medium. GSA instruments use liquid nitrogen and gas media as adsorbent media. Based on the specifications of the Silica Gel Standard JISS-0701, the characteristic parameters are: Density, Surface Area, Pore Volume and pore diameter. This parameter greatly influences the desiccant's ability in gas adsorption and desorption characteristics. Pore diameters based on the International Union of Pure Applied Chemistry (IUPAC) Classification 1994 [627] are divided into three groups, namely (1) Micropore material: 0.2-2 nm, (2) Mesopore material: 2-50 nm, and (3) Macropore material: 50-1000 nm. Desiccants that have the size of most micropores, generally have characteristic adsorption isotherms curves such as type I. Examples are some types of activated carbon material included in this type. The advantages of this type of gas adsorption power and solid particles are very high and the adsorption capacity is large because of the large porous volume. But the ability of desorption is very low. This type is suitable for use in media to reduce the levels of toxic gases and particles in air and water. This media is used once, it cannot be regenerated.

Mesopore and pore macro materials have the properties of type IV and V isotherm curves, which have a high adsorption and desorption power. This can be seen also from the curve there is a hysteresis area. But if the amount of adsorption power and desorption is equal, hysteresis on the isotherm curve is not visible, even though the desiccant material has desorption properties. The hysteresis area that is too wide is also not well used as an active medium in SDC, because it shows that the desiccant has low regeneration properties. The vapor / gas absorbed by the desiccant remains in the pore of the media, even though it has passed through the regeneration phase. Some types of desiccants also have an enlarged hysteresis area over time. Indeed, the desiccant material has a useful life. One indication of the ability of adsorption / desorption is that the hysteresis area is enlarged. The following table 1 is the main dimension of pore desiccant for standard silica gel and silica gel in many markets.

Table 1. The main dimensions of the desiccant pore standard JIS and Non-Indicating Silica Gel

Adsorbent	Surface Area (m ² /g)	Pore Volume (cm ³ /g)	Average pore diameter (nm)	Average pore width (4V/A)	Specific weight (g/cm ³)
Silica gel standard JISS-0701	650	0.36	2.2	2.21	0.7
Non-Indicating Silica Gel	600 - 800	0.35 – 0.45	2-3	-	0.7-0.77

In general, solid desiccant materials based on their sources can be divided into two, namely natural and synthetic types. The first type which is already available in nature can be directly utilized, while the second type needs to be synthesized with raw materials from nature. Adsorptivity / desorptivity of a solid material is determined by its surface structure. The surface of a solid desiccant containing pores is one of the main factors that determines adsorptivity / desorptivity. The more pores formed, the higher the adsorptivity / desorptivity. Rice husk on the surface has pores. The amount of pore can be increased, one of which is by combustion into rice hush ash. This combustion not only changes the surface structure but also the composition of compounds formed in solid desiccants. One parameter that affects adsorptivity / desorptivity is the composition of the compound. The composition of the rice husk

ash compound is also determined from the source or location of the rice field. To determine the composition of desiccant compounds XRF was tested.

The purpose of this research is therefore to explore the feasibility of rice husk that is used as an active ingredient of solid wheel desiccant on cooling machines of Solid Desiccant Cooling type. The desiccant performance of rice husk is compared to desiccant silica gel that is produced from quartz sand. This study uses raw materials for making silica gel samples from rice husk obtained from the rice fields in Sumedang district, west java, Indonesia. Characteristics testing uses laboratory facilities at: ITB, Unpad and UNY. The production of silica gel from rice husk is done simply at the Chemical Laboratory of Unpas Food Engineering Department. Pure silica gel that is used for comparable material, comes from many that are sold freely.

2. Experimental Method

Two different samples, namely the RRC silica gel which was widely marketed, but the specifications were not known. This sample is used as a comparison for the second sample from the burnt straw. This rice husk from the rice fields of Sumedang district (West Java). Stages of making rice husk ash samples include (1) Rice Husk gradation (sieving, filtering) by using 20-200 mesh sieves. The main part, which usually consists of a size of 20 mesh, is used for experiments, (2) Washing and drying with distilled water for the purpose of cleaning and drying the sun for 48 hours.

The characterization of desiccant materials uses two instruments, namely: Gas Sorption Analyzer (GSA) and X-Ray Fluorescence (XRF). GSA is used to determine the adsorption / desorption properties and the main dimensions of the desiccant pore sample material (pore surface area, pore diameter and pore volume). While XRF is used to determine the composition of desiccant compounds.

3. Results and Discussions

3.1. Adsorption / Desorption

Figure 5 illustrates the isothermic adsorption / desorption diagram N_2 at $-196^{\circ}C$ on SG (silica gel) and RHA (rice hull ash). The adsorption / desorption power of silica gel is much higher than that of rice husk ash. The hysteresis curve shows that more N_2 ash is left in the media pore compared to silica gel during the desorption process. Silica gel is more hydrophilic than ash. The silica gel isotherm curve seems to be included in the mixed type in the IUPAC classification; type II and type IV, while the isotherm curve of rice husk ash is a mixed type III and type IV. Thus, from the adsorption / desorption diagram, silica gel is better than rice husk ash as an SDC cooling system.

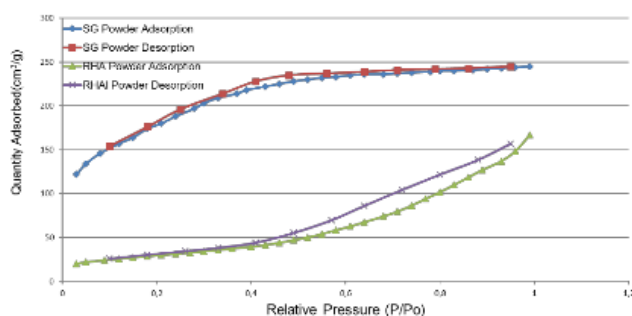


Figure 2. Graph of N_2 adsorption-desorption isotherm from silica gel and rice husk ash

3.2. Analysis of Pore Structure

To compare the texture properties of the adsorbent, the parameters obtained from the BET surface area, pore volume, pore diameter and microporosity are tabulated in Table 2. This table shows that the porous surface area of silica gel powder is 6x the surface area of pore rice husk ash, powder

Table 2. Characteristics of the pore texture of the adsorbent

Adsorbent	Surface Area (m ² /g)	Pore Volume (cm ³ /g)	Average pore diameter (nm)	Average pore width (4V/A)	Specific Weight (g/cm ³)
Silica Gel RRC	632	0.38	2.4	2.41	0.7
Rice husk ash	106	0.26	9.7	9.81	0.7

Rice husk ash pore volume is 2/3 parts volume of silica gel pore. The average diameter of the silica gel pore is 3x the average diameter of the porous ash. But based on pore size, silica gel and rice husk ash are included in the mesopore group

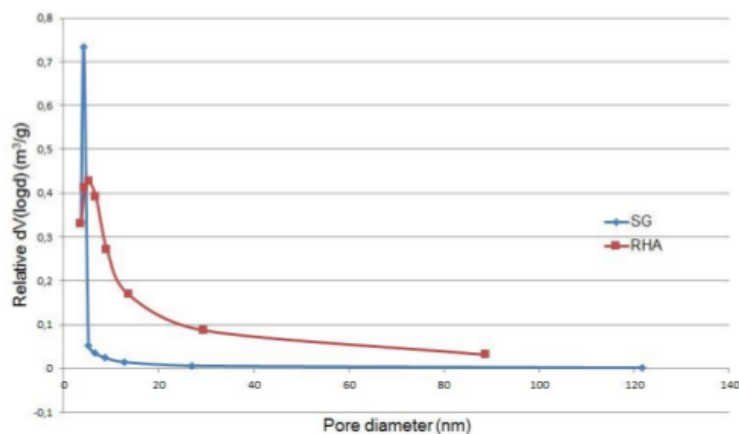


Figure 3. Pore size distribution desorption

The pore size distribution of silica gel and rice husk ash samples can be seen in Fig. 6. calculated from the N₂ adsorption isotherm following the method Barrett-Joyner-Halenda (BJH) with calibration. This is clearly shown in Fig. 6, Silica gel reveals a relatively narrow pore distribution centered around 2.4 nm, while the ash distribution is relatively wide at around 9.7 nm.

3.3. Desiccant Compound Composition Analysis

X-ray fluorescence (XRF) is an analytical technique that can analyze the compounds that make up a solid material. Nowadays with the development of XRF instrument technology, there is already a portable type, and its use is easier.

We are testing the composition of silica gel and ash compounds using ITB Mining Engineering laboratory facilities.. Composition of adsorbent compounds can be seen in table 3. From the table it can be seen that the purity of silicon oxide in rice husk ash is lower than silica gel. Rice husk ash content of silicon oxide is 94.95% while silica gel is 99.83%.

Table 3. Composition of the adsorbent compounds Silica gel and rice husk ash

Components expressed as oxides	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O	K ₂ O	MnO	TiO ₂	MgO	P ₂ O ₅
Silica Gel RRC	99.83	0.61	0.02	0.54	0.25	0.25	0.94	0.16	0.04	0.13
Rice husk ash	94.95	0.39	0.26	0.54	NA	0.02	0.94	0.16	0.02	0.9

The shape of the surface texture of the adsorbent material is very determined from the purity of silicon oxide and the temperature of treatment [8]. Surface texture parameters: pore surface width, pore diameter, pore distribution and pore volume. High purity adsorbents, wider pore surface and, average pore size including mesoporous groups. Temperature treatment process too high, above 1000 °C the phase structure formed is crystal. Crystal structure is not desirable, because the surface textures have no pores.

The results of the analysis showed that the rice husk ash or RHA in this study showed that the properties of the adsorbent were lower compared to silica gel. If it is used as a desiccant media on SDC its performance is 1/6 (if seen from the pore surface area) the performance of silica gel. Thus, technically, rice husk ash without treatment is not suitable to be used as SDC desiccant media. Some research results in the form of synthesis or modification of RHS [8-10] can improve the performance of the adsorbent. Thus the RHS is potential as a substitute for silica gel for desiccant media in SDC cooling systems.

4. Conclusion

Rice husk ash which is processed simply without a specific treatment, it is concluded that it has not yet fulfilled the technical requirements as SDC desiccant media. The absorptivity performance of rice husk ash can be increased in several ways, namely: treatment with the aim of increasing the purity of silicon oxide and making composite desiccant with basic ingredients of rice husk ash.

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