Drinking Water Filter from Rice Husk Ash

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The objective of this study was to prepare water filtering material from rice husk ash. The material was obtained by dissolving rice husk ash in sodium hydroxide solution and neutralized with HCl. The chemical composition of material was SiO₂, Al₂O₃, Fe₂O₃ and Na₂O in the values of 98.50, 0.49, 0.04 and 0.13 %, respectively. The morphology of material was undefined solid with BET surface area of 245.98 m²/g, average porosity of 13.38 nm and total pore volume of 0.76 cm³/g. The material was evaluated its filtration efficiency. The filter cartridge with 1.5 cm diameter and 9 cm long was made from 5 g of material and was assemble to a water filtering model. The filter capacity for water was up to 3 L and filtrated water was determined its quality index. Water quality parameters of the filtrate such as conductivity, turbidity, total dissolved solids and total hardness were lowered by 10.13, 94.72, 5.68 and 13.08 %, respectively, of the prior treated water.

Keywords: Rice husk ash, Silica gel form rice husk ash, Filter material.

INTRODUCTION

Rice husk is considered as an agricultural waste and was estimated to be produced globally 132,000,000 tons in 2008. The main components of rice husk are cellulose (25-35 %), hemicelluloses (18-21 %), lignin (26-31 %), silica (15-17 %), soluble (2-5 %) and moisture about 7.5 %. Burning rice husk ash as fuel to generate energy is used by many industries. After complete combustion, rice husk ash is produced as new waste. This rice husk ash residuals contain about 87-97 % of silica with small amount of alkalies and other trace elements. Rice husk ash can be used as a low cost raw material for production of silica gel and powders. Silica gel is an amorphous which has a rigid three-dimensional network of colloidal silica. Type of silica gel is classified as aquagel (pores are filled with water), xerogel (aqueous phase in the pores is removed) or aerogel (removed solvent in the pores by supercritical extraction). In normal manufacturing, silica gel is prepared from sodium silicate, which produced from melting quartz sand with sodium carbonate at 1300 °C. The process is expensive due to its high energy-consumption. The silica gel uses in various applications such as adsorbents, ultrafilters and chromatography column packing materials. However, the silica xerogel can be readily produced by dissolving silica from rice husk ash with alkali solution at 100 °C to form sodium silicate and subsequently forming silica aquagel by adding hydrochloric acid to lower pH to 7. After removal of aqueous phase, silica aquagel is reformed to silica xerogel.

In this study, silica gel was prepared from rice husk ash by so-gel method and its properties were characterized by several techniques. The obtained silica gel was applied a filter for a homemade mobilizable water filtering kit. The filtrated water was determined its quality index. This demonstrates the usage of agricultural waste by converting into the rice husk ash, which is environmental friendly, reusable and low cost.

EXPERIMENTAL

All chemicals were purchased from Sigma-Aldrich Company. FTIR spectra were recorded on a Nicolet 6700 FT-IR spectrophotometer. Surface area analysis was done using Autosorb-1 surface area and pore size analyzer. Quantitative chemical analysis was carried out on a Bruker AXS SRS 3400 X-ray fluorescence spectrometry (XRF). Micrographs images were obtained on a LEO 1450 scanning electron microscopy (SEM).

Silica gel production: Silica gel was prepared by the sol-gel method. Silica was extracted from 100 g of rice husk ash by refluxing with 500 mL of 1 M NaOH for 3 h with constant stirring to dissolve the silicate to produce a sodium silicate.
The solution was filtered through nylon membrane filter with a 1 µm pore size and the residue was washed with 100 mL of hot water. The mixture of filtrate and washing were allowed to cool to room temperature. The filtrate was the sodium silicate solution, used to neutralized sodium silicate solution, with addition of drop wise to 100 mL 1 M of hydrochloric acid and aged for 24 h. The silica aquagel obtained was washed with deionized water and dried in a hot air oven at 70 °C for 48 h to give silica xerogel.

Characterization of silica gel: Silica gel produced from rice husk ash was characterized by several techniques. The functional groups present in products confirmed by Fourier transform infrared spectroscopy, using attenuated total reflectance technique (ATR) with resolution of 1 cm⁻¹ and scan range of 400 to 4000 cm⁻¹. The microstructures were investigated with a SEM at an accelerated voltage of 15 kV, at a beam angle of 90°. The surface area, the average pore sizes and the total pore volume of particles were measured using BET method under nitrogen adsorption at liquid nitrogen temperature. The chemical compositions were determined using X-ray fluorescence spectroscopy to determine the percentage of SiO₂ and impurities in products.

Homemade mobilizable water filtering kit design: The mobilizable drinking water filtering kit was designed based on: (1) easy to use, (2) exchangeable filter cartridge and (3) low cost. The filtering kit components are shown in Fig. 1. Commercially available plastic pipe with 1.5 cm in diameter and 9 cm in height was packed with 5 g of silica gel produced from rice husk ash using as the filter cartridge (a). Raw water constrained in reused PET bottle (b) was passed through the filter cartridge when increasing pressure in bottle by handle air compressor (c).

RESULTS AND DISCUSSION

Silica gel produced from rice husk ash: The silica gel produce from rice husk ash by the sol-gel method was silica xerogel, which was irreversible gel. Photographs of the rice husk ash, silica aquagel and silica xerogel are shown in Fig. 2. Density and shrinkage of silica gel due to concentration of sodium silicate and pH of gelation. However, the silica gel prepared by this method has sodium as contaminant which can be removed by washing with water.

Fourier transform infrared spectroscopy (FTIR) analysis: Commercial silica gel and silica gel produced from rice husk ash were similar in IR spectrum. The FTIR spectra are shown in Fig. 3.

FTIR spectrum showed that the bands from 470 to 450 cm⁻¹ were assigned to bending vibration of O-Si-O. Also the bands from 1100 to 1070 cm⁻¹ and from 810 to 790 cm⁻¹ were assigned to the stretching vibration of Si-O-Si. Band from 1650 to 1620 cm⁻¹ corresponds to -OH bending vibration. Broad band from 3500 to 3400 cm⁻¹ were due to the chemically absorbed water and also due to the surface hydroxyl groups. The silica gel surface consists of two types of functional groups, siloxane (Si-O-Si) and silanol (Si-OH). The silica gel should be highly polar due to silanol groups on surface. It can adsorbed polar substances with strong affinity.

Scanning electron microscopy: Morphology of silica gel produce from rice husk ash was studied using scanning electron microscopy. Scanning electron micrographs were captured under various magnifications, shown in Fig. 4. The
morphology of material was undefined solid which have porous distributed on surface. The SEM image of silica gel produce from rice husk ash at 3,500X (b), clearly observed the small pores are scattered on the heterogeneous surface are created by the etching of NaOH within the material\textsuperscript{15}.

**Surface area analysis:** Results of BET method found that the surface area of 245.98 m\textsuperscript{2}/g, average porosity of 13.38 nm and total pore volume of 0.76 cm\textsuperscript{3}/g. The pores size according to mesopore (2-50 nm)\textsuperscript{16}. The number of porous, pore size and pore volume are the main reason affecting the surface area of material and adsorption efficiency.

**X-Ray fluorescence results:** Components analysis of materials, determined by using XRF is shown in Table-1. The results showed that inorganic content of this silica gel has a high amount of silica dioxide (95.10 %) and a few impurities. The Na\textsubscript{2}O contaminated due to neutralized of sodium silicate with HCl in sol-gel method. Chemical compositions of both commercial silica gel and silica gel produced from rice husk ash confirmed their chemical similarity. Silicon dioxide was found to be a major component of both silica gels.

<table>
<thead>
<tr>
<th>Table-1</th>
<th>CHEMICAL COMPOSITION OF SILICA GEL PRODUCED FROM RICE HUSK ASH AND COMMERCIAL SILICA GEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica gel</td>
<td>Chemical composition (%)</td>
</tr>
<tr>
<td></td>
<td>SiO\textsubscript{2}</td>
</tr>
<tr>
<td>Produced from rice husk ash</td>
<td>95.10</td>
</tr>
<tr>
<td>Commercial</td>
<td>98.50</td>
</tr>
</tbody>
</table>

**Water quality analysis:** The silica gel produced from rice husk ash was used as a water filter. The filter cartridge packing with 5 g of materials was assembled to a homemade mobilizable water filtering kit. The filtration process was carried out by compressing air into raw water bottle by handle air compressor. Filtrated water was collected and determined its quality index. The results are shown in Table-2.

<table>
<thead>
<tr>
<th>Table-2</th>
<th>RAW WATER AND FILTRATED WATER QUALITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Unit</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>-</td>
</tr>
<tr>
<td>Conductivity (EC)</td>
<td>µS/cm</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>mg/L</td>
</tr>
<tr>
<td>Hardness</td>
<td>mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>mg/L</td>
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<tr>
<td>Chromium</td>
<td>µg/L</td>
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<tr>
<td>Lead</td>
<td>µg/L</td>
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</tbody>
</table>

ND = Not detected; A\textsubscript{1L} = Raw water; A\textsubscript{2L} = First liter filtrated water; A\textsubscript{3L} = Second liter filtrated water; A\textsubscript{4L} = Third liter filtrated water

Conclusion

The characteristics of silica gel produced from rice husk ash were similar to commercial silica gel. It has the BET surface area of 245.98 m\textsuperscript{2}/g and pore size of 13.38 nm corresponding to a mesopore. The main of chemical composition was SiO\textsubscript{2} (95.10 %). The filter cartridge packing with 5 g of silica gel produced from rice husk ash can filtering raw water up to 3 liter. The post-treated water quality such as conductivity, turbidity, total dissolved solids and total hardness were found to be lowered by 10.13, 94.72, 5.68 and 13.08 %, respectively. As the results, the mobilizable drinking water filtering kit have been able to filter in raw water about 3 L which have a good quality for drinking.

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**REFERENCES**