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SEMINAR NASIONAL TEKNIK KIMIA "KEJUANGAN" 2013

*Pengembangan Teknologi Kimia
untuk Pengolahan Sumber Daya
Alam Indonesia*

5 Maret 2013

**PROGRAM STUDI TEKNIK KIMIA
FAKULTAS TEKNOLOGI INDUSTRI
UPN "VETERAN" YOGYAKARTA**

PROSIDING





PUPUK KALTIM



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TEKNIK KIMIA "KEJUANGAN" 2013.**

*Pengembangan Teknologi Kimia untuk
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Yogyakarta, 5 Maret 2013*

Hak Cipta ada pada Program Studi Teknik Kimia

Teknologi Industri UPN "Veteran" Yogyakarta
Jl. SWK 104 (Lingkar Utara) Condongcatur, Yogyakarta (55283)

Dilarang mengutip sebagian atau seluruh buku ini atau diperbanyak dengan tujuan komersial dalam bentuk apapun tanpa seijin Program Studi Teknik Kimia Fakultas Teknologi Industri UPN "Veteran" Yogyakarta, kecuali untuk keperluan penulisan artikel atau karangan ilmiah dengan menyebutkan buku ini sebagai sumber.

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Reviewer
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Anggota	: Ir. Dyah Tri Retno, MM



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Makalah Bidang Kajian

A. Perpindahan Massa dan Panas

Kode	Judul, Penulis dan Alamat
A1	The Performance of Controlled Freeze Out Area Double Pipe Heat Exchanger in Removing CO₂ From CH₄-CO₂ Gas Mixture <i>Ibnu Eka Rahayu, Ardila Hayu Tiwikrama, Setiyo Gunawan, dan Gede Wibawa*</i> Department of Chemical Engineering, Faculty of Industrial Technology Sepuluh Nopember Institute of Technology Kampus ITS Sukolilo Surabaya, 6011. Tel/Fax :+62-31-5946240/+62-31-5999282 <i>*E-mail: gwibawa@chem-eng.its.ac.id</i>
A2	Evaluasi <i>Performance</i> Injeksi Air pada Lapangan Minyak "X" Didukung dengan Pelaksanaan <i>Surveillance</i> dan Perencanaan <i>Water Injection Plant</i> Sederhana <i>Hariyadi¹, Novian Aribowo²</i> Program Studi Teknik Perminyakan, Fakultas Teknologi Mineral, UPN "Veteran" Yogyakarta Jl. SWK 104 (Lingkar Utara), Condong Catur, Yogyakarta 55283





- A3 **Kajian Teknologi Dehumidifier Untuk Pengeringan Obat Herbal**
Sri Utami Handayani¹⁾
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- A4 **Evaluasi Proses Dehidrasi Gas Alam Menggunakan Triethylene Glycol (Teg)**
Anas Puji Santoso
Program Studi Teknik Perminyakan, UPN "Veteran" Yogyakarta
- A5 **Pengaruh Isopropyl Alkohol Pada Laju Etsa Silikon (100) dengan Larutan KOH dan TMAH**
Slamet Widodo
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E-mail: widodo@ppet.lipi.go.id, slametwidodo50@gmail.com
- A6 **Studi Etsa Elektrokimia dari Silikon (100) Dengan Larutan CsOH dan KOH**
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E-mail: widodo@ppet.lipi.go.id, slametwidodo50@gmail.com
- A7 **Mass Transfer Model for Basic Blue Adsorption onto Pillared Bentonite Clay Using Langmuir Equilibrium and Taking into Account the Intra Particle Concentration Gradient**
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^{*}Department of Chemical Engineering, Gajah Mada University, Yogyakarta 55281, Indonesia
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- A8 **Studi Pemanfaatan Condensate Outlet Steam Trap Sebagai Air Umpan Boiler di PT. Pupuk Sriwidjaja Palembang**
Alfa Widyawan^{1} dan William Kusnanto¹*
¹Departemen Perencanaan dan Pengendalian Produksi, PT. Pupuk Sriwidjaja Palembang
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^{*}E-mail: alfa@pusri.co.id

B. Termodinamika

Kode Judul, Penulis dan Alamat

C. Teknologi dan Pengendalian Proses

Kode Judul, Penulis dan Alamat

- C1 **Analisa Pengujian Kualitas, Kompatibilitas, *Scaling Tendency* dan Mikrobiologi Air Injeksi untuk Penerapan *Waterflooding* di Lapangan Minyak**
Dedy Kristanto
Program Studi Teknik Perminyakan, Fakultas Teknologi Mineral, UPN "Veteran" Yogyakarta
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- C2 **Efek Pencampuran Tepung Peuyeum dan Tepung Singkong Terhadap Tekstur dan Rasa Roti Tawar**
Andy Chandra, Judy Retti Witono, dan Sabrina
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- C3 Peningkatan Perolehan Minyak Dengan *Co₂ Flooding***
Edgie Yuda Kaesti^{1}, I Putu Suarsana^{2*}, Dedi Cahyoko Aji^{3*}*
¹ Jurusan Teknik Perminyakan Fakultas Teknologi Mineral UPN "Veteran" Yogyakarta
² EOR Pertamina EP
³ Mahasiswa MTG Teknologi Mineral UPN "Veteran" Yogyakarta
- C4 Pembentukan Batubara, Komponen Maseral dan Mineralnya serta Pemanfaatannya Sebagai Energi**
Edy Nursanto^{1,6}, Arifudin Idrus², Hendra Amijaya³, Subagyo Pramumijoyo⁴, Harli Talla^{5,1}*
¹ Program Doktor, Jurusan Teknik Geologi, Universitas Gadjah Mada, Yogyakarta
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⁶ Program Studi Teknik Pertambangan FTM UPN "Veteran" Yogyakarta
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- C5 Pengolahan Larutan Zat Warna *Disperse Red* Menggunakan Metode Elektrokoagulasi dengan Elektroda Aluminium**
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Universitas Katolik Parahyangan, Ciumbuleuit 94 Bandung 40141 Indonesia
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- C6 Optimasi Reaksi Oksidasi Pati Ubi Kayu dengan Proses Ozonasi: Pengaruh pH dan Temperatur Operasi**
Isti Pudjihastuti, Siswo Sumardiono, Edy Supriyo
Laboratorium Food Process Engineering, Jur Teknik Kimia, Fak Teknik, Universitas Diponegoro
Jl. Prof. Sudharto, SH, Tembalang, Semarang, 50239, Telp/Fax: (024) 7471359
E-mail: lstipudjihastuti@gmail.com
- C7 Dynamic Study of Bioethanol Production from Cheese Whey using *Kluyveromyces marxianus* (DSMZ 7239)**
Akbarningrum Fatmawati, Rudy Agustriyanto*
Jurusan Teknik Kimia, FT, Universitas Surabaya, Jl Raya Kalirungkut Surabaya 60292
- C8 Cyclohexane Oxidation in a Series of Stirred Tank Reactors**
Rudy Agustriyanto, Akbarningrum Fatmawati
Chemical Engineering Department, Surabaya University, Jalan Raya Kalirungkut Surabaya
E-mail: rudy.agustriyanto@gmail.com
- C9 Penggunaan Teknologi Hydrothermal Di Daerah Titik Kritis Air Dalam Reaksi Degradasi Gliserol**
Yuyun Yunlati¹, Sumarno², Mahfud²
¹ Jurusan Teknik Kimia, ITATS, Jl. Arief Rahman Hakim No.100 Surabaya
² Jurusan Teknik Kimia, ITS, Kampus ITS Sukolilo, Surabaya
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- C10 Effect of Sonication on the Crystallinity and Hydrolysis Products of Cellulose**
Sumari¹, Achmad Roesyadi², dan Sumarno³
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- C11 Pengaruh Penggunaan *Blowing Agent Methylene Chloride* dan Karbondioksida Terhadap Struktur *Polyurethane Foam***
*Sofiatun Anisah, Yahma Muhammad Sakti, dan Sumarno**
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- C12 **Production of Glycerol Carbonat from by Product Transesterification using Nickel Catalyst**
Bambang Poedjojono, Diah Agustina Puspitasari, Santi Dyah Savitri
Jurusan Teknik Kimia, Fakultas Teknologi, Universitas WR. Supratman,
Jl. Arief Rachman Hakim No. 14 Surabaya
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- C13 **Performance and Robustness of Multivariable Feedback Process Systems I: Principal Gain Analysis**
Marthen Luther Doko
Department of Chemical Engineering, Institut Teknologi Nasional Bandung
*Corresponding Author's E-mail: mldoko@yahoo.com
- C14 **Performance and Robustness of Multivariable Feedback Process Systems II: Stability and Robustness**
Marthen Luther Doko
Department of Chemical Engineering, Institut Teknologi Nasional Bandung
*Corresponding Author's E-mail: mldoko@yahoo.com
- C15 **Degradasi Kitosan Dengan Proses Hidrotermal pada Berbagai Variasi Konsentrasi Asam Asetat**
*Anitarakhmi Handaratri, Emma Savitri, dan Sumarno**
Program Studi Teknik Kimia, FTI, Institut Teknologi Sepuluh Nopember
Kampus Keputih Sukolilo Surabaya, Jawa Timur
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- C17 **Degradation of Leachate from Municipal Solid Waste Final Disposal Using Two Stage Fixed Bed Anaerobic Reactors**
H. Budlástuti^{1}, E. Muhari¹, D. Widayabudningsih², M. Ghozali¹*
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²Chemical Analyst Study Program,
Chemical Engineering Department, State Polytechnic of Bandung
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D. Kinetika Reaksi dan Katalisis

- | Kode | Judul, Penulis dan Alamat |
|------|--|
| D1 | Pemanfaatan Bijih Besi sebagai Katalis Dalam Pencairan Batubara
<i>Haril Talla^{1,2*}, Hendra Amiljaya¹, Sugeng Spto Suryono¹, I Wayan Warmada¹,
Edy Nursanto^{1,3}</i>
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| D2 | The Effect of Promotor on Catalyst Activity to Transesterification of Palm Oil
<i>Santi Dyah Savitri, Achmad Roesyadi</i>
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Jurusan Teknik Kimia, Fakultas Teknologi Industri,
Institut Teknologi Sepuluh Nopember Surabaya
E-mail: aroesyadi@yahoo.com |
| D3 | Transesterifikasi Minyak Jarak Pagar Menggunakan NaOH dan Ca(OH)₂ sebagai Katalis
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Laboratorium Teknologi Proses Program Studi Teknik Kimia, FTI,
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Kampus ITS Sukolilo Surabaya, Jawa Timur 60111
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E. Bioteknologi

- | Kode | Judul, Penulis dan Alamat |
|------|--|
| E1 | Validasi Proses Menggunakan Media Fill
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| E2 | Analisis Asam Sianida (HCN) pada Beberapa Genotip Ubi Kayu (<i>Manihot esculenta</i>, Crantz.)
Djumhawan Ratman Permana ^{1*} , Sari Nengsih ² , N. Sri Hartati ¹ dan Enny Sudarmonowati ¹
¹ Pusat Penelitian Bioteknologi-LIPI, Cibinong,
² Mahasiswa Program Studi Farmasi, ISTN- Jakarta
[*] E-mail: pdjumhawan@yahoo.com |
| E3 | Isolasi Enzim Bromelin Dalam Bentuk Serbuk dari Buah Nanas
Ronny Kurniawan, S.Juhanda, Aditia Nugraha, Irfan Djatnika
Jurusan Teknik Kimia, Fakultas Teknologi Industri Itenas Bandung
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E-mail : ron_itenas@yahoo.com |
| E4 | Seleksi <i>In Vitro</i> Tunas Ubi Kayu (<i>Manihot esculenta</i> Crantz) Genotip Iding untuk Ketahanan Terhadap Kekeringan Menggunakan Media Polietilen Glikol (PEG-6000)
Dody Priadi ^{1*} , Eka Desi Lestari ² , Hani Fitriani ¹ dan N.S Hartati ¹
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² Departemen Biologi, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Indonesia
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| E5 | Multiplikasi Tunas <i>In Vitro</i> Benih Asal Pohon Sengon Unggul Menggunakan Nodal Kotiledon
N. Sri Hartati, Dodi Priady and Enny Sudarmonowati
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| E6 | Peningkatan Kapasitas Produksi dan Uji Praktis ¹³¹I-MIBG Sebagai Radiofarmaka
Diagnosa dan Terapi Neuroblastoma
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Pusat Radioisotop dan Radiofarmaka BATAN
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| E8 | Produksi Protein Sel Tunggal dari Jamur dengan Substrat Kulit Singkong (<i>Manihot utilissima</i>)
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F. Optimasi Teknologi Pemisahan

- | Kode | Judul, Penulis dan Alamat |
|------|---|
| F1 | Penurunan Kadar Garam Dalam Air Laut Dengan Proses Elektroforesis : Kajian Awal
M.Syahri ¹ dan Tjukup Marnoto ²
^{1,2} Program Studi Teknik Kimia, FTI, UPN "Veteran" Yogyakarta
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H. Teknologi Pengolahan Limbah

Kode Judul, Penulis dan Alamat

- H1 **Pengolahan Skala Pilot Limbah Cadmium dan Sianida Industri Elektroplating dengan Fotokatalisis UV/TiO₂**
Tedi Hudaya, Shirleen Rosemarie, dan Regina Leoni*
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- H2 **Pengolahan Skala Pilot Limbah Kromium Heksavalen Industri Elektroplating dengan Fotokatalisis UV/TiO₂**
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- H3 **Identifikasi Limbah Pada Proses Batik**
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- H4 **Penurunan Kekeruhan Air Tambang Menggunakan Larutan Alum**
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Jalan Lingkar Utara SWK 108 Condong Catur Yogyakarta
- H5 **Utilization of Industrial Tapioca Wastewater for Making Nata de Cassava as Paper Material**
Sirin Fairus, Netty K., Arlinda Indreswari, dan Ade Christine Arltonang
Jurusan Teknik Kimia Itenas Jl PHH. Mustafa No 23 Bandung
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- H6 **Hidrolisis Limbah Tongkol Jagung Menjadi Glukosa Menggunakan Katalis Asam Klorida**
Emmanuela M. Widianti dan Rispiandi
Teknik Kimia – Politeknik Negeri Bandung, KBK Sistem Proses
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- H7 **Electrode Dimension Effect to Electrocoagulation Performance**
Bambang Hari. P¹. and Hendriyana¹
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* bhpjtk@yahoo.co.id
- H8 **Pengolahan Lindi Menjadi Biogas Menggunakan Digester Anaerobik Dua Tahap**
Mukhtar Ghozali, Dewi W, Ade T.N, Ilham F
Jurusan Teknik Kimia Politeknik Negeri Bandung (Polban)
Jl. Gegerkalong Hilir, Ciwaruga Bandung, Telp./Fax. : 022.2016403
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- H9 **Kinerja Flokulan Starch-graft-polyacrylamide (St-g-PAM) Terhidrolisis Dalam Penghilangan Warna Pada Limbah Cair**
Gilang Agung Prabowo dan Sumarno
Jurusan Teknik Kimia, Fakultas Teknologi Industri, Institut Teknologi Sepuluh Nopember (ITS),
Kampus ITS. Jl. Teknik Kimia, Sukolilo, Surabaya-60111
*E-mail: onramus@chem-eng.its.ac.id





- H10 **Pengolahan Limbah Cair CN/Cd²⁺ dan Cr(VI) Industri Elektroplating**
Tedi Hudaya¹, Martin Wijaya Kusuma
Magister Teknik Kimia, Program Pascasarjana, Universitas Katolik Parahyangan
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- H11 **Pengaruh Oil Sludge Pertamina Surabaya terhadap Kuat Tekan Keramik Tradisional**
Adi Ilcham¹, Dyah Tri Retno², Alan Syahputra³, M. Novie Aprianto^{1,2,3,4}
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- H12 **Studi Awal Pengolahan Limbah dengan Beban COD-BOD Tinggi Secara Koagulasi-Flokulasi.**
Tanjung Wahyu Widayati¹, Mahreni¹, Herman², Muhammad Catur S.W²
1) Dosen Prodi Teknik Kimia, Fakultas Teknologi Industri, UPN "Veteran" Yogyakarta
2) Mahasiswa Prodi Teknik Kimia, Fakultas Teknologi Industri, UPN "Veteran" Yogyakarta
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- H13 **Processing Biochar from Solid Waste of Arenga Pinnata Flour Industry**
Susanti Rina Nugraheni¹⁾, Agus Prasetya²⁾, and Sihana³⁾
¹Program Studi Teknik Kimia, FTI, UPN "Veteran" Yogyakarta
Jln. SWK 104 (Lingkar Utara), Condongcatur, Yogyakarta
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³Physics Engineering Department, UGM, Jalan Grafika 2, Kampus UGM, Yogyakarta
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- H14 **Pengolahan Limbah Cair Industri Tahu Melalui Proses Anaerobik**
Siti Diyar Kholisoh, Abdullah Effendi, Dwi Ratna Mayasari, dan Rahma Wulan Febriati
Program Studi Teknik Kimia, Fakultas Teknologi Industri, UPN "Veteran" Yogyakarta
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I. Energi Baru dan Terbarukan

- | Kode | Judul, Penulis dan Alamat |
|------|---|
| I1 | Preparation of Biodiesel from Kemiri Sunan (<i>Aleurites trisperma</i>) Oil Using Dolomite as Solid Catalyst
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| I2 | Pembuatan Biodiesel Menggunakan Katalis Limbah Kulit Telur
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| I3 | Kajian Awal Pembuatan Biodiesel Menggunakan Katalis Asam Berbahan Dasar Campuran D-Glukosa dan Pati Jagung
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- 14 **Kajian Kinerja dan Keekonomian Rancangan Gasification Stove Berbasis Limbah Pertanian**
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Fax. (022) 6642064, e-mail suhartono@lecture.unjani.ac.id
- 15 **Pre-treatment Process of Biodiesel Production From Waste Cooking Oil**
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- 16 **Pengaruh Delignifikasi Menggunakan NaOH pada Hidrolisis Jerami Padi Menggunakan Asam Sulfat Encer**
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- 17 **Specification and Classification of Bio-lubricant Base Fluid from Ring Opening of Epoxidized Methyl Oleate**
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J. Teknik Produk

- | Kode | Judul, Penulis dan Alamat |
|------|--|
| J1 | Pengaruh Konsentrasi Ferosulfat Terhadap Ketahanan dan Ketahanan Warna Hasil Celupan Kain Batik Katun Dengan Ekstrak Daun Ketapang
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| J2 | Pengaruh Waktu Fermentasi Pada Pembuatan Zat Warna Indigo (<i>Indigofera Tinctoria</i>)
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E-mail: hastuti2121@gmail.com |
| J4 | Sintesis Garam Mohr [Besi (II) Amonium Sulfat Hidrat : $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6 \text{H}_2\text{O}$]
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- J5 **Karakteristik Ekspansi Termal dan Elektrokimia Komposit Katoda $\text{La}_{0.6}\text{Sr}_{0.4}\text{Co}_{0.2}\text{Fe}_{0.8}\text{O}_{3-\delta}$ -SDC Karbonat untuk Solid Oxide Fuel Cell Bersuhu Rendah dan Menengah**
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- J6 **Pengaruh Suhu Pencampuran dalam Proses Pembuatan Kompon terhadap Viskositas Mooney, Karakteristik Vulkanisasi, Bound Rubber, Degree of Crosslinking dan Sifat Fisik Karet Alam**
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- J7 **Peranan Ubi Kayu dalam Pengembangan Industri Tepung Mokaf**
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- J8 **Pembuatan Arang Aktif dari Campuran Cangkang dan Serabut Sawit dengan Aktivator Na_2CO_3**
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- J9 **Studi Pengaruh Suhu, Waktu Reaksi dan Perbandingan Mol Reaktan Terhadap Konversi Reaksi Sulfonasi Pada Produksi Metil Ester Sulfonat**
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- J10 **Preparasi Kit Cair Tetrafosmin untuk Deteksi Kanker dan Perfusi Jantung**
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- J11 **Pengaruh Perbandingan Umpan dan Suhu Pada Proses Pelarutan Zirkonium Hidroksida (ZOH)**
Tundjung Indrati Y, Sudaryadi, Mulyono (Pusat
Teknologi Akselerator dan Proses Bahan ,BATAN)
- J12 **Kajian Potensi Pasar Produk Karbon Dan Grafit Menggunakan Bahan Pitch Dan Coke**
Tunjung Indrati Y
Pusat Teknologi Akselerator dan Proses Bahan ,BATAN
- J13 **Pembuatan dan Analisis Sifat Kuliner Mie Instan Kering Oven dari Komposit Tepung Gandum dan Tepung Gadung**
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- J14 **Pembuatan Surfaktan Berbahan Dasar Jerami Padi**
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Indeks Penulis Makalah

Indeks Kata Kunci





Mass Transfer Model for Basic Blue Adsorption onto Pillared Bentonite Clay Using Langmuir Equilibrium and Taking into Account the Intra Particle Concentration Gradient

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Abstract

Bentonite clay from Pacitan, East Java, was made using intercalation and pillarization method, using cationic surfactant HDTMA-Cl as intercalating agent and NaOH – AlCl₃ mixture with OH/Al ratio was 0,8 as pillaring agent at 80°C. Furthermore, calcination was done at 500°C for 4 hours. Adsorption process was done at laboratory scale batch system with initial Basic Blue 41 dye concentration varied between 100 ppm, 200 ppm, 300 ppm, 400 ppm, and 500 ppm for adsorbent mass ratio was 0,1 g/L and adsorbent size of 100 mesh. Adsorbent mass ratio was varied 0,1 g/L; 0,2 g/L; 0,25 g/L; 0,35 g/L; and 0,4 g/L for initial dye concentration of 600 ppm. Adsorption equilibrium was analyzed using Langmuir equilibrium model, and kinetic model was developed with considering convection mass transfer at adsorbent surface and intra-particle dye diffusion. Mathematic model and experimental data was used to calculate dye convective mass transfer and effective diffusion coefficient using computer program. The result showed that Basic Blue 41 – pillarized bentonite clay equilibrium obeyed Langmuir equilibrium model. Developed kinetic model was relatively fitted to experimental data. Maximum dye removal was 97.947 %. Generally, Basic Blue 41 adsorption kinetic was controlled by film resistance at adsorbent surface and intra-particle diffusion resistance.

Keywords: Adsorption; Basic Blue; Bentonite Clay; Modeling; Pillarization

1. Introduction

Bentonite clay, which was composed of alumina-silicate, is a low price commodity, widely available, and considered to be an effective sorbent material having a high added value. Based on the mineral content, the clay can be divided into: smectite (montmorillonite), kaolinite, halloysite, chlorite and illite [Olphen et al., 1977]. Bentonite is a type of clay which has the ability to adsorb water and its cation exchange power much greater than the ordinary clay. A component of the dominant clay mineral in bentonite is montmorillonite. Montmorillonite has the chemical formula $[Na_xAl(2-x)Mg_x(Si_4O_{10})(OH)_2] \cdot (H_2O)_n$.

Montmorillonite clay minerals are a group that has a good ability to adsorb both the metal and the organic molecules. It also has an ability to inflate and deflate (swelling) and an exchangeable cation [Pinnavaia, 1983]. Bentonite is a clay composed of alumina-silicate which consists of 3 layers, where a layer containing octahedral aluminum flanked between the other two layers containing tetrahedral silicate. This three layers form a sheet structure [Astrology, 2000].

Due to its large porosity, beside its potential as an adsorbent, bentonite clay is very suitable to be used as catalysts and ion exchange material. However, although bentonite clay is very useful in many areas of application, it has limitations in maintaining its shape, due to its nature of easy to swell. Clays can swell due to hydration, deflate and even the structure of the clay can be damaged by dehydration and heating. To prevent this deformation, the interlayer region should be supported by a stable pillar. The other purpose of such modification is to create a large pore volume. In addition, it was also addressed to increase its ability of maintaining the porosity of clay despite hydration and dehydration occur. This process is called pillarization [Robert et al., 1999].



Two main steps of the pillarization process were as follows, 1). Inserting a pillaring agent to the layer between the clay sheets, 2). Calcining the material to make the pillaring agent incorporated and tied into the solid sheets strongly. The so-called pillaring agent is any substance that can form the pillars on sheets of clay, so the clay becomes porous. While, the insertion of these substances into the space between the sheets (interlayer) without changing the structure of the sheet is called intercalation stage. Bentonite that has undergone a process of pillarization is called pillared bentonite clay [Robert et al., 1999].

To form a stable pillared bentonite with permanent porosity, the process of heating (calcination) needs a great consideration. The best temperature range for calcination is between 300-500 °C [Barrer et al., 1978]. Pinnavia described that the calcination process at the temperature range makes the pillaring agent strongly bind to the bentonite clay sheets. This is indicated by the spectral data A1 MAS-NMS on smectite clays pillared with Al (Barrer et al., 1978). After experiencing pillarization, the pillared bentonite clay has expands vertically compared to prior pillarization, and can not return to the original form despite the dehydration happen [Robert et al., 1999].

Besides being able to expand vertically due to dehydration, other characteristics of pillared bentonite is having basal spacing at least 0.315 to 0.353 nm. The pillaring agent molecules are laterally in the area of intermellar which has porous characteristic. However, the basic criteria of pillared bentonite is having a good thermal and chemical stability and having a good distribution of the pillars in the intermellar region [Robert et al., 1999].

The aim of this research work is to develop a mass transfer model which is suitable for basic blue adsorption onto pillared bentonite clay by taking into account the intra particle concentration gradient and applying linear equilibrium equation. The suitability of the model was examined by using the data of laboratory experiments and analyzed quantitatively.

2. Theory and Experimental

2.1 Modeling

Since the pillared bentonite clay particles used in this research work is sphere-like shape, it was considered appropriate to assume the shape of pillared bentonite to be spherical shape, then the mass transfer model was developed using volume element mass balance for sphere:

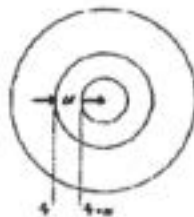


Figure 1. Volume element mass balance

$$\begin{aligned}
 m_{in} - m_{out} &= m_{acc} \\
 \left(-D_e A_{\pi r^2} \frac{\partial C}{\partial r} \right)_r - \left(-D_e A_{\pi r^2} \frac{\partial C}{\partial r} \right)_{r+\Delta r} &= 4\pi r^2 \Delta r \frac{\partial (C_{\mu} + C)}{\partial t} \\
 \frac{\partial}{\partial r} \left(r^2 \frac{\partial C}{\partial r} \right) &= \frac{\partial}{\partial t} (C_{\mu} + C) \\
 \frac{\partial^2 C}{\partial r^2} + \frac{2}{r} \frac{\partial C}{\partial r} &= \frac{1}{D_e} \frac{\partial}{\partial t} (C_{\mu} + C)
 \end{aligned} \tag{1}$$

If $q = C_{\mu} + C$ then

$$\frac{\partial^2 C}{\partial r^2} + \frac{2}{r} \frac{\partial C}{\partial r} = \frac{1}{D_e} \frac{\partial q}{\partial t} \tag{2}$$

With



$$\begin{aligned}
 q &= C_{\mu} + C \\
 &= \frac{\alpha C}{C + \beta} + C \\
 Cq + \beta q &= \alpha C + C^2 + \beta C \\
 C^2 + (\alpha + \beta - q)C - \beta q &= 0
 \end{aligned}
 \tag{3}$$

Solution of the equation (3) is

$$\begin{aligned}
 C_{1,2} &= \frac{-(\alpha + \beta - q) \pm \sqrt{(\alpha + \beta - q)^2 + 4\beta q}}{2} \\
 C &= \frac{-(\alpha \rho_p + \beta - q) \pm \sqrt{(\alpha \rho_p + \beta - q)^2 + 4\beta q}}{2\varepsilon}
 \end{aligned}
 \tag{4}$$

Equation (2) is the general form of differential equation for adsorption of solute from liquid phase to solid sphere which was taken into account the intra-particle concentration gradient. Differential equation (2) was solved using finite difference approximation which expressed as:

$$\left(\frac{i-1}{iM}\right)C_{i-1,j} - \frac{2}{M}C_{i,j} + \left(\frac{i+1}{iM}\right)C_{i+1,j} + q_{i,j} = q_{i,j+1}
 \tag{5}$$

$$M = \frac{(\Delta r)^2}{D \Delta t}
 \tag{6}$$

For a certain position in spherical shape, it is necessary to modify the general finite difference equation as follow:
At the center of the sphere ($i = 0$)

$$q_{0,j+1} = -\frac{6}{M}C_{0,j} + \frac{6}{M}C_{1,j} + q_{0,j}
 \tag{7}$$

At solid surface ($i = N$)

$$q_{N,j+1} = \left[D \frac{\beta}{\alpha} \frac{C_{N,j} - C_{N-1,j}}{(\Delta r)^2} + \frac{k_c A \pi R^2 (C_{AL} - C_{N,j})}{\alpha \Delta r} \right] \Delta t + q_{N,j}
 \tag{8}$$

Solute concentration in the liquid phase (C_{AL}) was calculated using the equation:

$$C_{AL,j+1} = C_{AL,0} - \frac{4\pi N R}{V} \int_0^R r^2 q dr
 \tag{9}$$

There are several methods available to solve the finite difference approximation such as explicit (forward), implicit (backward) and Crank-Nicolson [Wahyudi Budi Sediawan and AgusPrasetya, 1997]. In this research work, the finite difference approximation equation was solved using explicit method. The suitability of the model was examined by evaluating the sum of squares of errors (SSE) which was expressed as:

$$SSE = \sum (C_{model} - C_{experimental})^2
 \tag{10}$$

2.2 Experiment

Bentonite clay, which was originated from Pacitan, East Java – Indonesia, was treated following intercalation and pillarization method. The measurement of some physical properties such as density, total porosity, macro and micro pore size and surface area BET (Brunauer, Emmet, Teller) was conducted afterward. Cationic surfactant (HDTMA-Cl) was used in intercalation while sodium hydroxide and $AlCl_3$ was used during pillarization process. The C.I. Basic Blue 41 under the trade name T/A Blue RGN-T 200% was used as adsorbate.

Intercalation is performed by preparing bentonite suspensions in which the ratio of bentonite/water = 1 gram/50 ml was applied and was diluted using distillate water to 1000 ml of total mixing volume. Surfactant was then added to the bentonite suspension and was stirred for 5 hours at a temperature of 80 °C. The weight ratio of surfactant/bentonite used was 1: 25. After being stirred for 5 minutes the solution was cooled briefly and was separated from the filtrate by a vacuum pump and then was dried in a laboratory scale oven at 100°C for 1 hour.

Pillaring agent was made by mixing NaOH and $AlCl_3$, in which the ratio of OH/Al was 0.8, at a temperature of 80°C and was stirred until homogeneous mixing was reached. Intercalated bentonite suspensions was stirred and heated until the temperature reaches 80°C. After that pillaring agent, ratio of Al/bentonite = 10 mmol/gram, was



added gradually to a suspension of intercalated bentonite and stirred for 5 hours at 80°C. After 5 hours, bentonite was separated from the filtrate using a vacuum pump and dried in an oven at 100 °C for 1 hour. Finally the bentonite was calcined at 500°C in a laboratory scale furnace for 4 hours with a gradual increase to the calcination temperature every 15 minutes to avoid a collapse in the structure of pillared bentonite. To ensure uniformity, cool pillared bentonite powder then passed to a 100 mesh sieve prior the analysis of surface area BET and other physical and chemical characterization. Pore radius, pore surface area and pore volume was analyzed using NOVA Data Analysis Package Ver. 2.00, Quantachrome Corporation.

Adsorption test of Al pillared bentonite powder was performed using an artificial waste which was prepared by dissolve a basic blue dye in 500 ml distilled water. Experiments were conducted by varying the initial dye concentration and bentonite weight /solution volume ratio. During the batch experiment, the dye concentration changes in liquid phase was detected by taking samples and measure the concentration using an UV spectrophotometer.

3. Results and Discussion

The scanning electron microscope (SEM) image of original and pillared bentonite was shown on Figure 2 and Figure 3, respectively. The effect of the pillarization treatment was shown by the different surface appearance of the two images. The pillared bentonite image showed clearly the formation of basal spacing and area of intermellar where the pillaring agent molecules are laterally distributed.

The result of the composition analysis of the original and pillared bentonite was shown on Table 1. It could be seen from the table that the mass fraction of aluminum oxide increased to some significant extent, i.e. from 18.23 %w to 54.16 %w. The increasing aluminum oxide content is due to the infiltration of pillaring agent $AlCl_3$. Then, it indicated that the pillarization process has strongly incorporated and tied the pillaring agent into the bentonite solid sheets. While the mass fraction of some components including silicon dioxide, calcium oxide and ferro oxide decreased as consequent of increasing the aluminum oxide content.

Larger pore volume was detected on pillared bentonite which reflects increasing the surface area after pillarization. Accumulated pore volume and pore surface area were presented on Figure 4 and Figure 5, respectively. The figures showed clearly that the pillarization increased pore volume and pore surface, significantly. There has been a tremendous shift of pore size distribution dominates, from 0-20 Angstroms for the original bentonite to 20-500 Angstrom for pillared bentonite.

Figure 6 and Figure 7 displays basic blue concentration in the liquid phase by comparing the experimental data to the calculated value from the model for variations in the initial concentration. While Figure 8 and Figure 9 displays the same thing for variations in the ratio of mass of bentonite to volume of solution.

The parameters associated with the calculation of dye concentration, which include the distribution constant, external mass transfer coefficient and diffusivity coefficient, generated during solving the finite difference approximation were presented in Table 2 and Table 3.

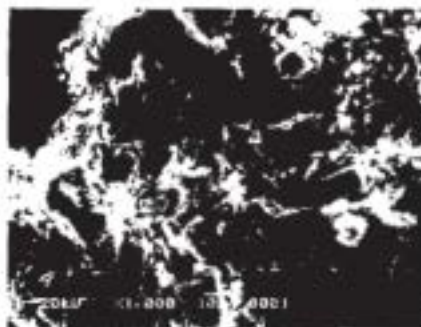


Figure 2: Scanning electron microscope image of original bentonite at magnification 1000x



Figure 3: Scanning electron microscope image of pillared bentonite at magnification 1000 x

Table 1: Composition of Original and Pillared Bentonite

Component	Original bentonite, %w	Pillared bentonite, %w
Na ₂ O	0,05	0.54
MgO	3.70	2.32
Al ₂ O ₃	18.23	54.16
SiO ₂	68.69	40.91
CaO	3.90	0.06
TiO ₂	0.59	0.16
FeO	4.83	1.85

Analisis metode : SNI 0449-2010

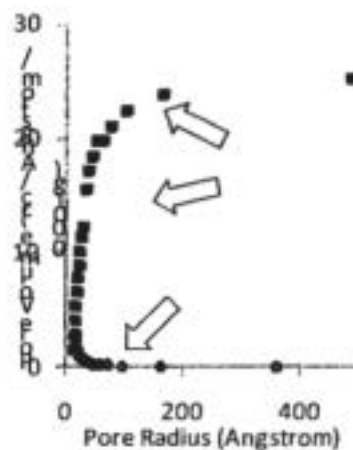


Figure 4: Accumulated pore volume versus pore radius of original and pillared bentonite clay.

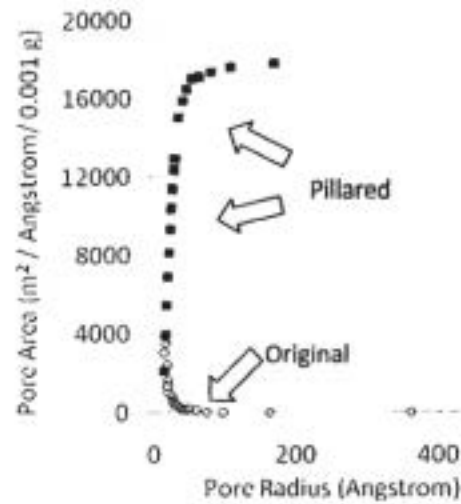


Figure 5: Accumulated pore surface area versus pore radius of original and pillared bentonite clay.

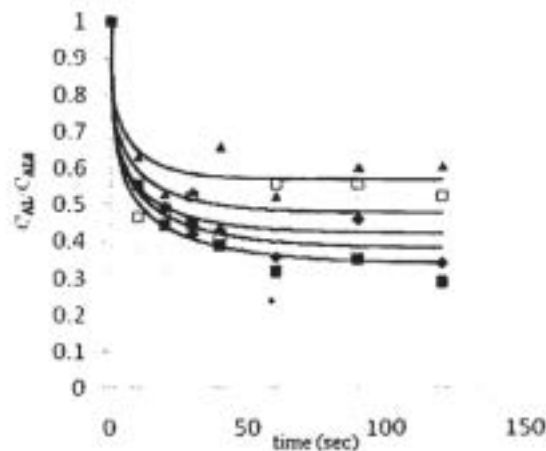


Figure 6: Basic blue concentration ratio in liquid phase versus time. The experimental data symbol for related initial concentration: ■ 100 ppm, ○ 200 ppm, ▲ 300 ppm, □ 400 ppm, ◆ 500 ppm. The curved line expressed the calculated result from the model. The mass ratio of bentonite/solution: 0.10 g/100 ml.

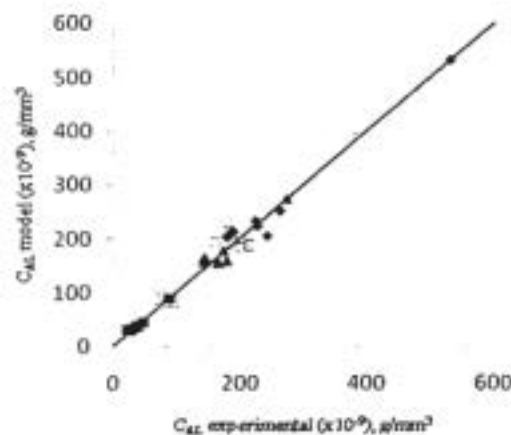


Figure 7: Basic blue concentration in liquid phase, model versus experimental data. The experimental data symbol for related initial concentration: ■ 100 ppm, ○ 200 ppm, ▲ 300 ppm, □ 400 ppm, ◆ 500 ppm. The mass ratio of bentonite/solution: 0.10 g/100 ml.

Distribution constants for dye adsorption by bentonite was apparently not affected by the dye concentration in solution, while an increase in the ratio of bentonite/solution slightly lowering the distribution constant value as was shown on Table 2 and Table 3. It wasn't found a clear correlation between the external mass transfer coefficient and the initial dye concentration as well as the bentonite/solution ratio.

Varying the initial concentration of dye at constant bentonite/solution ratio and varying the bentonite/solution ratio at constant initial dye concentration mean varying the dye concentration during the batch adsorption process.

While value of the external mass transfer coefficient calculated from the same experimental data source vary, as shown in Table 2 and Table 3. It mean that a change of dye concentration might be result in a change of an eddy diffusivity and/or the thickness of liquid phase interface film, since an external mass transfer coefficient depend on both the eddy diffusivity and the thickness of liquid phase interface film.

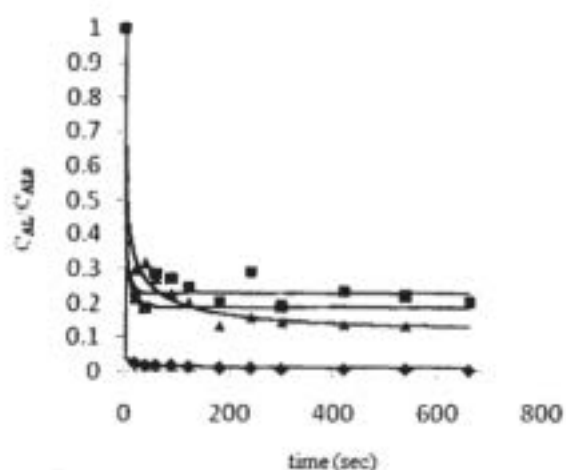


Figure 8: Basic blue concentration ratio in liquid phase versus time. The experimental data symbol for related bentonite/solution ratio: ■ 0.20 g/100 ml, ○ 0.25 g/100 ml, ▲ 0.35 g/100 ml, ◆ 0.40 g/100 ml. The curved line expressed the calculated result from the model. The initial concentration of basic blue was 600 ppm.

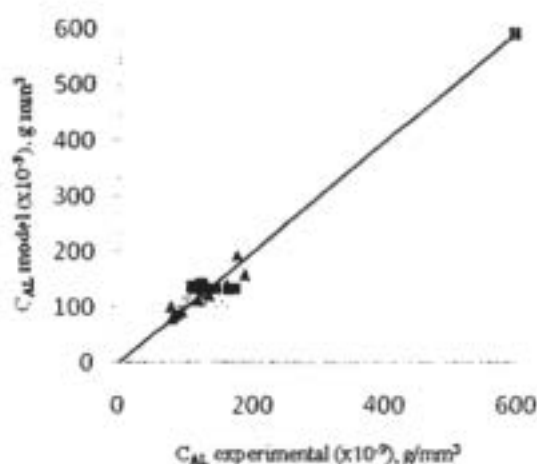


Figure 9: Basic blue concentration in liquid phase, model versus experimental data. The experimental data symbol for related bentonite/solution ratio: ■ 0.20 g/100 ml, ○ 0.25 g/100 ml, ▲ 0.35 g/100 ml, ◆ 0.40 g/100 ml. The curved line expressed the calculated result from the model. The initial concentration of basic blue was 600 ppm.



Table 2: Equilibrium, kinetic parameter, and SSE at various initial dye concentration for bentonite/dye solution ratio 0.1g/100 ml

C_{AL0} ppm	α (L/mg)	β (L/mg)	k_c cm/s	D_e cm ² /s	SSE
100	2.5	56.35	5.5	$6.6 \cdot 10^{-4}$	$6.7 \cdot 10^{-17}$
200	2.5	80.84	2.8	$7.0 \cdot 10^{-4}$	$1.8 \cdot 10^{-15}$
300	2.5	145.5	2.5	$7.0 \cdot 10^{-4}$	$1.5 \cdot 10^{-15}$
400	2.5	101.2	2.7	$6.6 \cdot 10^{-4}$	$5.7 \cdot 10^{-15}$
500	2.5	67.90	5.5	$6.6 \cdot 10^{-4}$	$2.7 \cdot 10^{-15}$

Table 3: Equilibrium, kinetic parameter, and SSE at various bentonite/dye solution ratio for initial dye concentration 600 ppm

B/D g/100 mL	α (L/mg)	β (L/mg)	k_c cm/s	D_e cm ² /s	SSE
0.2	1.2	39	8.0	$1.4 \cdot 10^{-3}$	$5.5 \cdot 10^{-15}$
0.25	1.5	38	5.0	$7.0 \cdot 10^{-3}$	$5.1 \cdot 10^{-15}$
0.35	1.5	34	0.9	$8.0 \cdot 10^{-3}$	$2.2 \cdot 10^{-15}$
0.4	59.2	101	17.0	$1.5 \cdot 10^{-3}$	$6.5 \cdot 10^{-17}$

The sum of squares of errors which was used to examine the suitability of the developed model was presented in Table 2 for initial dye concentration variation and in Table 3 for bentonite/solution ratio variation. The value were in the range of 6.510^{-17} – 5.710^{-15} . This low value of SSE indicates that the developed mass transfer model is suitable for basic blue adsorption onto pillared bentonite clay.

4. Conclusion

The effect of the bentonite pillarization was shown by the different surface appearance which was found on the scanning electron microscope images. The formation of basal spacing and area of interlayer was identified in the pillared bentonite.

After pillarization, the mass fraction of aluminum oxide increased to some significant extent, i.e. from 18.23 %w to 54.16 %w. The increasing aluminum oxide content is due to the infiltration of pillaring agent $AlCl_3$. It indicated that the pillarization process has strongly incorporated and tied the pillaring agent into the bentonite solid sheets.

Larger pore volume was indicated by pillared bentonite which reflects increasing the surface area after pillarization. There has been a tremendous shift of pore size distribution dominates, from 0-20 Angstroms for the original bentonite to 20-500 Angstrom for pillared bentonite.

This research work has proven that the developed mass transfer model are suitable for basic blue adsorption onto pillared bentonite clay.

Acknowledgements

The authors wish to thank The Technological And Professional Skills Development Sector Project (TPSDP) – ADB Loan No: 1792 – INO for providing the scholarship. Financial support from The University of Surabaya is gratefully acknowledged.





Nomenclature

B/D	bentonite/dye solution ratio (g / 100 ml)
CAL	solut concentration in liquid phase (mol/ml)
CAL_0	initial solut concentration in liquid phase (mol/ml)
C^*	solut concentration in liquid phase interface (mol/ml)
$C_{i,j}$	solut concentration at position i at time j
C_μ	solut concentration in solid (g/g solid)
D_e	diffusivity coefficient (cm ² /s)
V	Volume Solution (ml)
k_c	external mass transfer coefficient (cm/s)
M_{in}	rate of mass inflow (mol/s)
M_{out}	rate of mass outflow (mol/s)
M_{acc}	rate of mass accumulated (mol/s)
N	total number of particle
R	sphere radius (cm)
r	distance from the sphere center in radial direction (cm)
t	time (s)
<i>Greek letters</i>	
ϵ	particle porosity
ρ_{ads}	adsorbent density (g/ml)
α, β	konstanta Langmuir (L/mg)

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Lembar Tanya Jawab Moderator: Tjukup Marnoto

1. Penanya : Mujahid (Teknik Kimia, UPN "Veteran" Yogyakarta)
Pertanyaan : Selain Al apakah dapat digunakan logam yang lain?
Jawaban : Selain Al, dapat digunakan Zn, sSemua logam dapat dipakai. Untuk minyak atsiri dipakai Fe. Untuk zat warna dipakai Al 95,6%.

2. Penanya : Dinda Tri G. (Teknik Kimia, UPN "Veteran" Yogyakarta)
Pertanyaan : Mengapa menggunakan bentonit?
Jawaban : Adsorben yang murah bermacam-macam, karena dipasaran banyak bentonit yang tidak terpakai. Dulu untuk menyerap minyak atsiri dan zat warna basa lainnya.

3. Penanya : Dr. Ir. Tjukup Marnoto, MT (Teknik Kimia, UPN "Veteran" Yogyakarta)
Pertanyaan : Bagaimana jika pori berpori lagi?
Jawaban : Pori ada tiga macam: makropori, mesopori dan mikropori. Jadi dari data BET menggunakan mesopori.





Indeks Penulis Makalah

Penulis	Kode Makalah	Penulis	Kode Makalah
Abdul Aji Kresna Tri Anggara	J14	Diah Susetyo Retnowati	J13
Abdullah Effendi	H14	Didi Setiarto	MS
Abidin	F4	Dini Kurniawati	D3
Abu Hasan	J6	Diyoo Ikhsan	F7
Achmad Halim Purbohandono	I5	Djumhawan Ratman Permana	E2
Achmad Roesyadi	C10, D2	Dody Priadi	E4, E5
Adang Hardi G	E6	Dwi Ratna Mayasari	H14
Ade Christine Aritonang	H5	Dwi Suheryanto	J1, J2
Ade T.N	H8	Dyah Tri Retno	H11
Adi Ilcham	H11	E. Muhari	C17
Aditia Nugraha	E3	Edgie Yuda Kaesti	C3
Adityo Ramadhan	C5	Edy Nursanto	C4, D1
Agus Prasetya	H13	Edy Supriyo	C6
Agustanhakri Bakri	J5	Eka Desi Lestari	E4
Agustinus Ngatin	J4	Emma Savitri	C15
Akbarningrum Fatmawati	C7, C8	Emmanuela M. Widyanti	H6
Alan Syahputra	H11	Emmanuela Maria Wijayanti	J4
Alfa Widyawan	A8	Enny L.	E1
Anas Puji Santoso	A4	Enny Sudarmonowati	E2, E5
Andri Cahyo Kumoro	J13	Evy Nur Afriyanti	I6
Andy Chandra	C2	Faizah Hadi	E8
Anies Mutiari	F3	Fatmayati	J8
Anitarakhmi Handaratri	C15	Gatot Trilaksono	I6
Anna R.	E1	Gede Wibawa	A1
Ardila Hayu Tiwikrama	A1	Gigih Atmaji	I7
Arenst Andreas	C5	Gilang Agung Prabowo	H9
Arief Budiman	I5	Gloria Marcella Morgen Wiria	I3
Arif Andrianto	J9	H. Budiastuti	C17
Arifudin Idrus	C4	Hadiatni Rita Priyantini	A7
Aris Setyadi	I2	Hambali	F4
Ariinda Indreswari	H5	Hani Fitriani	E4
Aswati Mindaryani	F3	Hariyadi	A2
Bambang Hari. P	H7	Harli Talla	C4, D1
Bambang Poedjojono	C12	Hary Sulistyono	J6
Benny Lubiantara	MS	Hendra Amijaya	C4
Catarina Sri Budiayati dan	J13	Hendra Amijaya	D1
Cecep Taufik Rustendi	J10	Hendriyana	F8, H7
D. Widyabudiningsih	C17	Herlina	F4
Dadang	E1	Herman	H12
Dedi Cahyoko Aji	C3	Herry Santoso	I2, I3
Dedy Kristanto	C1	Heryoki Yohanes	I7
Dewi W	H8	I Putu Suarsana	C3
Diah Agustina Puspitasari	C12	I Wayan Warmada	D1





Penulis	Kode Makalah	Penulis	Kode Makalah
Ibnu Eka Rahayu	A1	Pujianti Intan P	I4
IGS Budiawan	J14	Purwoko	E6
Ika Perwitasari	J14	Putri Restu Dewati	I5
Ilham F	H8	R.P. Djoko Murwono	J13
Imam Prasetyo	A7	Rahma Wulan Febriati	H14
Indah Prihatiningtyas D.S	F7	Regina Leoni	H1
Indrihapsari	E8	Rispiandi	H6
Irene Tedjasaputra	I3	Rizki Kurniasih	E8
Irfan Djatnika	E3	Rochmadi	A7, J6
Isti Pudjihastuti	C6	Ronny Kurniawan	E3
Ivan Kristianto	I2	Rudy Agustriyanto	C7, C8
Jarot Raharjo	J5	S.Juhanda	E3
Juan August Naldo	H2	Sabrina	C2
Judy Retti Witono	C2	Santi Dyah Savitri	C12, D2
Kadarisman	F4	Sari Nengsih	E2
Karyadi	E6	Setiyo Gunawan	A1
Kusyanto	F6	Shirleen Rosemarie	H1
Laksmi Andri A	E6	Sihana	H13
Leonardo Arief	H2	Silvia Wulandari	I4
Lies Susilaning Sri Hastuti	H3, J3	Sirin Fairus	H5
M. Ghozali	C17	Siswo Sumardiono	C6
M. Novie Aprianto	H11	Siti Diyar Kholisoh	H14
M.Syahri	F1	Slamet Widodo	A5, A6
Mahfud	C9, D3, F6	Sofiatun Anisah	C11
Mahreni	H12	Sri Wahyu Murni	J14
Marthen Luther Doko	C13, C14	Sri Aguswarini	E6
Martin Wijaya Kusuma	H10	Sri Setyowati	E6, J10
Mega Kasmiyatun	F2	Sri Suhenry	H4
Mentik Hulupi	J4	Sri Sukadarti	E8
Mohamad Endy Yulianto	F2	Sri Utami Handayani	A3
Muhammad Catur S.W	H12	Sri Wahyuni Santi R	J14
Mujinah	E1	Srihastini	E1
Mukhtar Ghozali	H8	Subagyo Pramumijoyo	C4
Mulyono	J11	Sudaryadi	J11
N. Sri Hartati	E2, E5	Sugeng Sapto Suryono	D1
N.S Hartati	E4	Suharto Honggokusumo	J6
Nadiem Anwar	I6	Suhartono	I4
Nancy Siti Djengar	I1	Suharwadji Sentana	J7
Netty K	H5	Sumari	C10
Ninik Lintang	I1	Sumarno	C9, C10, C11, C15, H9
Nita Aryanti	F7	Supranto	H4
Novian Aribowo	A2	Suprpto	J9
Priyono Kusumo	F2	Surya Madya	MU2



Penulis	Kode Makalah	Penulis	Kode Makalah
Susanti Rina Nugraheni	H13	Wibowo	F5
Tedi Hudaya	H1, H2, H10	Widyastuti	J10
Tjukup Marnoto	F1	Widyastuti W	E1
Tundjung Indrati Y	J11, J12	William Kusnanto	A8
Tunjung Wahyu Widayati	H12	Wiratni	F3
Umi Nur Sholikha	F4	Yahma Muhammad Sakti	C11
Vonny Indah Sari	J8	Yeni Triyani	I6
Wahju Eko Widodo	I7	Yulius Deddy Hermawan	F5
Wahyu Bahari Setianto	I7	Yunilda	J10
Wahyudi Budi Sediawan	A7	Yuyun Yuniati	C9
War'an Rosihan	I4		





Indeks Kata Kunci

Kata Kunci	Kode Makalah	Kata Kunci	Kode Makalah
^{99m} Tc	F4	carbon	J12
^{99m} Mo/ ^{99m} Tc generator	F4	Carbon Dioxide	A1
^{99m} Tc yield	F4	carboxyl group	C6
^{99m} Tc-tetrofosmin	J10	cassava (Manihot esculenta, Crantz.)	E2, E4
a mixture of palm shells and fibers	J8	cassava flour	C2
Aceptic	E1	cassava peel	E8
acetic acid	C15	cassava starch	C6
Acid Catalyst	I3	catalyst	D1, H6
Acid value	I7	cellulose	C10
activated carbon	J8	ceramic	H11
Adsorption	A7, F3	cheese whe	C7
adsorption power of activated carbon to the iod solutions	J8	chemical activation	J8
Al electrodes	C5	Chemical Laboratory	H12
alum solvent	H4	chitosan	C15
Anaerobic digester	H8, H14	CO ₂ Flooding	C3
animal manure	H14	CO ₂ injection	F5
anyaman	J3	CO ₂ removal	F3
Arenga pinata waste	H13	Coagulation	H12
Basic Blue	A7	coal	C4
batik process	H3	Coal liquefaction	D1
Bentonite Clay	A7	coconut shell	I4
biochar	H14	color fastness	J1
Biodiesel	D2, D3, I1, I2, I3, I5	Compatibility	C1
bioethanol	C7	Composite	J5
biogas	H8, H14	compressive strength	H11
blowing agent	C11	concentration	F6
bound rubber	J6	consumer acceptance	J13
bread	C2	Conversion	J9
bromelain	E3	Cooking Oil	I2
bubble column photoreactor	H2	corn cob	H6, I4
Ca(OH) ₂ catalysts	D3	Corn Starch	I3
cadmium	H1	cotyledon node	E5
cadmium-cyanide	H10	CsOH	A6
Calcinated Waste Eggshell Catalyst	I2	culinary properties	J13





Kata Kunci	Kode Makalah	Kata Kunci	Kode Makalah
cyanide	H1	flocculation	H12
Cyclohexane	C8	flood balancing	A2
degradation	C9, C15	flow-rate	H8
degree of crosslinking	J6	gadung flour	J13
Dehumidifier	A3	gandapura	F2
delignification	H6	gasification stove	I4
delignified	I6	gaultherin	F2
dew point	A4	genotype	E2
D-Glucose	I3	ginger drying	A3
diagnosis	J10	glucose	C10, H6
dimension electrode	H7	gluten	C2
dissolution	J11	glycerol	C9, C12
Dolomite	I1	glycerol carbonat	C12
Double Pipe Heat Exchanger	A1	glycol losses	A4
double promotor	D2	graphite	J12
drought stress	E4	heat loss	A8
drying	A3	heat pump dryer	A3
dye binding by alkali	J2	hexavalent chromium	H2, H10
Dye solution	C5	hole scavenger	H2
dyes	H9	Hydrogen cyanide (HCN)	E2
Dynamic stud	C7	Hydrolysis	E10, H6, H9, I6
E shape	H7	hydrothermal	C9, C15
Electrochemical	J5	I-131	E6
Electrocoagulation	C5, H7	IAA	E5
electroplating	H1, H2, H10	indigo leaves	J2
Elektroforesis	F1	Injection Water Quality	C1
Elektrokimia	A6	injeksi	C3
emulsion	J14	instant noodle	J13
emulsion oil in water	F7	intensity	J1
Energy	A3, C4	IPA	A5
enhance oil recovery	F5	iron ore	D1
enzyme gaultherase	F2	iron powder	J4
Equilibrium	F3	isolation,	E3
esterification	I5	Jatropha curcas oil	D3
Etch stop	A6	Jet-loop fixed bed	F8
Etsa	A6	Kemiri Sunan	I1
Etsa Anisotropik	A5	KOH	A5, A6
faktor gesekan (fc)	F1	Lactic Acid Bacteria	J7
Fermentation	C7, E8, J2	Leachate	C17, H8
ferosulphate	J1	leaf ketapang extract	J1





Kata Kunci	Kode Makalah	Kata Kunci	Kode Makalah
lignin	J14	PBZ-TEOS	F4
lignosulfonate	J14	Pemanfaatan	J3
LT-ITSOFC	J5	Peng-Robinson EOS	A1
Lubricant	I7	Performance and Robustness	C13, C14
maceral	C4	peuyeum flour	C2
mass transfer	F8	Pillarization	A7
Media Fill	E1	pineapple	E3
Membrane	F7	pollution	H3
methane gas	C17	Polycrylamide	H9
methyl ester	J9	polyethylene glycol (PEG-6000)	E4
MIBG	E6	polyols	C11
Microbiology	C1	polyurethane foam	C11
microwave	F6	potential market	J12
mine water	H4	powder morphology	J11
mineral	C4	precipitation	E3
mixing temperature	J6	precursor	J12
mocaf characteristics	J7	Principal Gain Analysis	C13, C14
mocaf flour industries	J7	process condition,	J4
mocaf utilization	J7	pyrolysis	H13
Modeling	A7	quality standard	H4
Mohr salt	J4	radiochemical purity	J10
mordant	J1	radiopharmaceutical	E6
myocardial perfusion	J10	Radiopharmaceutical	E1
NaOCl	F4	rate of steam condensation	A8
NaOH	D3	reactor	C8
nata de cassava	H5	reducing sugar	I6
Natural Gas	A1	rendement	F6
natural gas dehydration process	A4	Resam	J3
natural rubber	J6	reservoir pressure	A2
network model	F5	Response Surface Methodology	C5
neuroblastoma	E6	rice straw	I6
Ni/ γ Al ₂ O ₃	C12	Ring opening esterification	I7
oil sludge	H11	RO membrane	H10
oligosaccharides	C10	Scaling Tendency	C1
oxidation	C6, C8	scaling up	E6
Oxirane content	I7	shoot induction	E5
P. Falcataria	E5	Si (100)	A6
palm oil	D2	Silikon (Si)	A5
paper	H5	simulation	C8, F5
patchouli alcohol	F6	single cell protein	E8





Kata Kunci	Kode Makalah	Kata Kunci	Kode Makalah
Singular Value Decomposition (SVD)	C13, C14	traditional	H11
sintesis	J4	Transesterification	D3, I1
soil amendment	H13	treatment efficiency	C17
solubility	C6	triethylene glycol	A4
solvent	F6	turbidity	H4
Starch	H9	two stage fixed bed anaerobic reactor	C17
Starch graft Polyacryamide	H9	Ultrafiltration	E3, F7
steam condensate	A8	ultrasonic	C10
stedy state time	J11	urea	C12
Sterile	E1	utilization	A8
Strong Base Anion Exchange Resin	F3	UV/TiO ₂ photocatalysis	H1, H2, H10
sulfonation	J9	Validation	E1
sulfuric acid	I6, J4	value chain	J12
support	D2	Vegetable oil	I7
surface facilities	F5	waste	H3, H11
surfactant	J9, J14	Waste Cooking Oil	I3, I5
Surveillance	A2	Waste water	H12
swelling power	C6	Water injection	A2
tapioca wastewater	H5	water injection plant	A2
TDZ	E5	Waterflooding	C1
temperature variable	H13	wheat flour	J13
textile waste water	H7	wheat flour substitution	J7
thermal efficiency	I4	yield	D2
Thermal Expansion	J5	zirconium hydroxide	J11
TMAH	A5	zirconium oxychloride	J11
tofu liquid waste	H14		





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3. Magister Teknik Geologi
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- Teknik Eksplorasi Sumberdaya Mineral
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- Teknik Sumberdaya Air Tanah
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- Manajemen Pemasaran
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- Keuangan Daerah
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