Sustainable Processes for Energy and Green Products

Prof. Dr. M. Suleman Tahir
Department of Chemical Engineering
University of Gujrat, Gujrat, Pakistan

Pathways For Sustainable development
Contents

• Problem; Impact of various Chemicals on Environmental Pollution
• Industrial Waste
• Biomass and its potential
• Proposed Sustainable Processes
• Possible valuable green chemicals
• Conclusion &
• Recommendation
Back Ground: Impact of Various chemicals on Environment
Increasing GDP at Cost?
Pollutions
Is this sustainable?
Pathways of Pollution
Sustainability and Process Engineering

[Diagram showing the cycle of photosynthesis, from sunlight to CO2, O2, and H2O, involving animal manure, vegetable biomass, fertiliser, organic wastes, anaerobic digestion, biogas, and electricity and heat.]
IPCC Report 2014

- CO₂ released from 1750-1969 = 1970-2013
- 3.7-4.8°C rise up to 2100

Alternative energy is a must to resist Climate Change
Life Styles on this planet
Advanced world and our resources

Sustainable world

Industrial world

Simple World

Atmospheric CO₂ at Mauna Loa Observatory

Past Discovery
Future Discovery
Production

Revisions backdated. Rounded with 3yr moving average.

THE GROWING GAP
Regular Conventional Oil

Ghawar (Saudi Arabia)
Samotlor (Siberia)
Prudhoe (Alaska)
Cantarell (Mexico)
Kashagan (Kazakhstan)
North Sea


Gb/a

3/10/2015
Ongoing climate change suggest that CO2 will need to be reduced from its current 385 ppm to at most 350 ppm, but likely less than that.

Despite rapid current CO2 growth, ~2 ppm/year, we show that it is conceivable to reduce CO2 this century to less than the current amount, but only via prompt policy changes.

http://www.aip.org/history/climate/co2.htm#L_M021
Solar Energy

Bio-chemical, energy

Atomic Energy

Hydro Energy

GeoThermal Energy

Wind Energy

• BIO-Refinery
• Bio-Butanol
• Bio-Ethanol
• Bio-Acetone
• Bio-Gas
• Bio-Diesel
• other chemicals etc
Biomass (Rice Husk, Straw)

- Combustion
- Gasification etc
- Silica Potential

- Aerobic digestion
- **Bio-degradation** or
- Sugar (pretreatment, Ionic liquid etc)
Coal Power Generation in Pakistan

THAR COAL
THE GATEWAY TO ENERGY SECURITY OF PAKISTAN

Mr. Ajez Ali Khan
Secretary to Govt. of Sindh
Coal & Energy Development Department
Managing Director, Thar Coal & Energy Board

www.sindmines.gov.pk

Clean coal dream a costly nightmare
By Michael Hawthorne
TRIBUNE WATCHDOG

Naperville, other suburbs in power-plant deal now face the prospect of rising electricity bills

Coal-fired power plant that will be one of the nation's largest sources of greenhouse gas pollution

The Prairie State Energy Thermal Power Station is under construction in Joliet, Illinois.

Policy incentives:
1. Coal Logistics assured by Pakistan Railways
2. Power Transmission assured by National Transmission & Despatch Company (NTDC)
3. Land Acquisition assured by the Government of Punjab
4. One Window Facility assured by Punjab Power Development Board (PPDB)

Pre-selected Locations:
-Qadisha (Lahij)
- Bhikki (Sheikhupura)
- Khairpur (Khairpur)
- Trind Sadawal (Rahim Yar Khan)
- Mona Syedan Wala (Muzaffargarh)
Energy and Environment-Challenges

CLIMATE CHANGE AND ENERGY INSECURITY

The Challenge for Peace, Security and Development

Edited by FELIX DODDS, ANDREW HIGGAM and RICHARD SHERMAN

Foreword by ACHIM STEINER
Regional Sustainable Approach (Asia) and Dealing with Wastes

- **Biomass to Bio-energy**
  - Agricultural Bio-mass potential
  - Dairy forming bio-mass potential
  - Various Wastes (fruit, vegetable market)
  - Algae for bio-fuels
  - Plants and forests

- **Industrial /**
  - Pulp and paper waste water containing lignin/black liquor etc
  - Citrus fruit and juice industry waste
Pathways for Orange Waste to Green Products (Case study)
Potential

- Total available potential of kinnow waste from juice industry is 0.17 million tons [2]. 1 ton of orange waste gives 11 gallon of ethanol [3] and 107.4 m³ biogas [4]. So given potential of orange waste produce $1.87 \times 10^6$ gallon of ethanol and $18.2\times 10^6$ m³ of biogas + green Chemicals
Black liquor from pulp and paper industry

- 1 kg of paper produced waste water (liters)?
- De-Polemerize lignin and Black liquor for green chemicals?

The oxygen blown circulating fluidized bed (CFB) gasification system with direct causticization shall be integrated with the pulp and paper mill. There will be no extra biomass to compensate total energy deficit. From our initial studies and calculation, it is concluded that considerable amount of synthetic gas production (about 21 MW) could be produced based on pulp mill capacity (about 47 MW of black liquor input) without any biomass import.
LCB Structure: Cellulose

Lignin
Hemicellulose

Cellulose

\[(C_6H_{10}O_5)_n \rightarrow nC_6H_{12}O_6 \quad \Delta H_r = +22.1n \text{ kJ/mol}\]

Crystalline cellulose

Cellulose molecule

Glucose

Celllobiose

\[D_p = 800-17,000 (6-10) \quad ; \quad MT = 225^\circ \text{C} - 425^\circ \text{C}\]
LCB Structure: Hemicellulose and Lignin

$p$-Coumaryl alcohol
Coniferyl alcohol
Sinapyl alcohol

Glc = glucose
Xyl = xylose
Gal = galactose
Fuc = fucose
Ara = arabinose

Pentose
Hexose

DP = 150-200
T = 130-220°C
Pretreatment of LCB
Major Crops of Pakistan

- Wheat: 24,000
- Sugarcane: 50,000
- Cotton: 3,000
- Rice: 7,000
- Millet: 3,000
- Maize: 296
# Rice Straw—Promising Feedstock

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>Sugars 32-47</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>Silica 19-27</td>
</tr>
<tr>
<td>Lignin</td>
<td>Biochar 5-24</td>
</tr>
<tr>
<td>Silica</td>
<td>7-12</td>
</tr>
</tbody>
</table>

~ 905 million ton/year
Sugar Industry of Pakistan

Units – 88
Molasses -2.25 M ton
Distilleries- 19
Ethanol– 0.5 M ton
Bioenergy and Biomaterials Pathways

1st

Pretreatment/Hydrolysis

Sugars (C5+C6)

Fermentation

Bioethanol

2nd

Solid Residue

Biosorbent

Silica

Biochar

Combined Heat & Power Generation

Syngas

Methanol

Biochar

Bio-oil

Anaerobic Digestion

Biohydrogen/Biogas

Biofertilizer

3rd
Key Targets for Effective LCB Pretreatment

There should be a common pretreatment technique that may meet all of the above targets.
Biorefinery for Biochemicals

Primary biorefinery

- Pretreatment & fractionation
- Hemi-Cellulose
- Cellulose

Secondary biorefinery

- Hydrolysis
- Conversion & synthesis
- Fermentation

IL

Lignocellulosic biomass & residual streams

- Thermochemical depolymerisation & conversion
- Lignin

- Chemical derivatives, e.g. surfactants
- Furfural
- Levulinic acid
- Ethanol
- Butanol
- Propanediol
- Lactic acid
- Platform chemicals, e.g. phenolics, styrene, ...
- Performance products
- Fuel additives
- Electricity
- Heat
Lignin Biorefinery

p-Coumaryl alcohol
Coniferyl alcohol
Sinapyl alcohol

Lignin
BioChemical: Lignin as A Chemical Precursor

Lignin As Chemical Precursors

New technology

Current technology

Sulfite waste liquor + CuO/CeO/NaOH + pine lignin → Oxalic, succinic, benzenepentacarboxylic, isophthalic, phthalic acid

24 hrs. 230°C 40 atm. air → Terephthalic acid
Conclusions

1. Pollution can be minimized with efficient processes
2. Sustainable approach towards waste treatments is applicable in south Asia
3. Bio-refinery from LCB for various chemicals is need of the day
4. Lignocelluloses biomass and lignin based black liquor from pulp and paper industry has Bio-refinery Potential
Recommendation

1. • Research in collaboration of industries for new technologies

2. • Research project base job at Universities (partially sponsored by industry (as in Europe & US)

3. • Behavior change for sustainable in every thing like ......
Preparation of tomorrow