Materials Science Modules: Math and Science for Sub-Saharan Africa

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Background and Introduction

- Africa is rich in mineral and materials resources
- However most students in Africa have never heard about materials science and engineering
- Hence most of their knowledge of math and science is abstract and not connected to the materials opportunities around them
- Furthermore the most students do not know much about how to add value to natural resources through processing
- There is therefore a need to develop materials modules that could increase the pipeline of students that can pursue future careers in materials
Materials – The Major Driver

- Science and technology are the major engines of development
- Materials have always been a major driver in technological change...
  - Alloys
  - Semiconductors
  - Polymers
  - ...

| Hard materials
| Soft materials

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Materials and Project-Based Approach

- **Advanced Materials (Bio and Nano)**
  - Targeting of disease
  - Alternative energy

- **Societal Development**
  - Affordable infrastructure e.g. recycling of agricultural & industrial waste
  - Value addition to people, minerals and natural products
Structure of the Presentation

• MS4SSA Materials Modules (Grades 11&12)
• Project-Based Modules
  – Water Purification
  – Clean Energy
• Implementation Strategy
Objectives of the MS4SSA Materials Modules

- Work with the New Jersey Center for Teaching and Learning (NJCTL) and the World Bank Team to develop modules for the teaching of materials science and engineering in African secondary schools.

- The modules are presented at a level that can be taught to students in the final year of secondary school.

- The modules include lecture materials, homework questions, answer keys and project-based modules:
  - Lecture materials (structure, properties, processing, materials selection and design)
  - Interdisciplinary project-based approach to solving African problems (clean water, clean energy)
Outline of MS4SSA Lecture Modules

- Introduction to materials science and engineering
- Crystal structure and crystallography
- Introduction to mechanical properties
- Plasticity and deformation
- Fracture and fatigue
- Phases and phase diagrams
- Materials and their mechanical properties
- Electrical properties of materials
- Biomaterials and bio-inspired design
- Materials selection and design
- Project-based modules – renewable energy/clean water
Project-Based Module on Clean Water

Project-Based Approach

• Identify societal problem and/or developmental need
• Explore possible solutions within a scientific and engineering framework
• Develop and test potential solution
• Propose potential strategies for going from ideas to markets/policy

From Problem to Solution
Background and Introduction to Clean Water Project

• The problem of contaminated water is the single biggest cause of the steep decline in life expectancy in Africa
  – Impact bigger than that of HIV
  – Example of Nigeria
  – 5000 lives lost per day

• Major problem is due to microbial pathogens (E.Coli)

• Other global challenges due to water contamination include chemical contamination (fluoride, arsenic and heavy metals) in Asia, Africa, Latin America

• Holistic approach needed to develop solutions from science to technology & evidence-based policy & entrepreneurship
# Water Treatment Methods

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Water</td>
<td>- 100% potable if boiled for at least 20 min.</td>
<td>- Requires time to gather fuel (fire wood)</td>
</tr>
<tr>
<td></td>
<td>- Can be done in the home all year round</td>
<td>- Requires time for heating and cooling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Causes a Change in the taste of water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Method does not remove turbidity</td>
</tr>
<tr>
<td>Adding Chlorine</td>
<td>- Effectively kills bacteria</td>
<td>- Effects the taste of water</td>
</tr>
<tr>
<td></td>
<td>- Simple to use</td>
<td>- Must be applied periodically</td>
</tr>
<tr>
<td></td>
<td>- Can be used anytime</td>
<td>- Does not remove turbidity</td>
</tr>
<tr>
<td></td>
<td>- Low cost technology</td>
<td>- Most be purchased and transported</td>
</tr>
<tr>
<td>SODIS</td>
<td>- Low cost</td>
<td>- Does not work in shade, night or rainy season</td>
</tr>
<tr>
<td></td>
<td>- Can be large or small</td>
<td>- Requires 4-6 hours to reach required to heat</td>
</tr>
<tr>
<td></td>
<td>- Remove turbidity</td>
<td>- Requires Time for water to cool</td>
</tr>
<tr>
<td></td>
<td>- Can be used</td>
<td>- Change in the taste of the Water.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Does not remove turbidity</td>
</tr>
<tr>
<td>Bio Sand Filter</td>
<td>- Can be large or small</td>
<td>- Appropriate sand must be available.</td>
</tr>
<tr>
<td></td>
<td>- Easy to use</td>
<td>- Does not remove microbio. contaminants</td>
</tr>
<tr>
<td></td>
<td>- Local materials</td>
<td>- Time to cultivate bio-sand.</td>
</tr>
<tr>
<td>Filtròn Water Filter</td>
<td>- Kills bacteria 99%</td>
<td>- Cost, US$ 7.50 to $25.00 (depending on country)</td>
</tr>
<tr>
<td></td>
<td>- Easy to use</td>
<td>- Heavy compared to the other systems.</td>
</tr>
<tr>
<td></td>
<td>- One time transportation</td>
<td>- Fragile, easy to break</td>
</tr>
<tr>
<td></td>
<td>- No change of taste</td>
<td>- Periodic cleaning is required (turbid water clogs the filtering element).</td>
</tr>
<tr>
<td></td>
<td>- Culturally acceptable</td>
<td>- Combustion for the production process</td>
</tr>
<tr>
<td></td>
<td>- Self-encased water</td>
<td>- Should be replaced after two years</td>
</tr>
<tr>
<td></td>
<td>Container permits serving.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Made locally</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Works all year around 24 hours a day</td>
<td></td>
</tr>
<tr>
<td>PuR (P&amp;G)</td>
<td>- Effective</td>
<td>- expensive ( US $ 4.20 a month )</td>
</tr>
<tr>
<td></td>
<td>- Good for emergencies</td>
<td>US $0.14 cents a day for 20 liters</td>
</tr>
</tbody>
</table>
Point-of-Use Water Filtration Systems
Materials Science: Surface Morphology and Chemical Composition - SEM/EDX

- Sawdust (Woodchips)
- Clay (Redart)
- Porous Ceramic

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Schematic Diagram

- Pathogen
- Pores
- Ag+ Particle Lining
Figure 2. Comparison of relative sizes of various contaminants in water. Based on these, the pore size of the ceramic filter, at 0.2μm, would be about the size of a full stop on this page.
**E. coli Filtration Tests of Non-Coated Ceramic Water Filters**

<table>
<thead>
<tr>
<th>Volume Fraction Clay:Sawdust</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Average ± Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>45:55</td>
<td>99.97</td>
<td>99.85</td>
<td>99.91 ± 0.06</td>
</tr>
<tr>
<td>50:50</td>
<td>99.99</td>
<td>99.93</td>
<td>99.96 ± 0.03</td>
</tr>
<tr>
<td>55:45</td>
<td>99.52</td>
<td>99.84</td>
<td>99.68 ± 0.16</td>
</tr>
<tr>
<td>65:35</td>
<td>99.99</td>
<td>99.99</td>
<td>99.99 ± 0.00</td>
</tr>
</tbody>
</table>
Filter Processing - From Ideas to Markets
Project-Based Module on Clean Energy

Project-Based Approach

- Identify societal problem and/or developmental need
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From Problem to Solution
Motivating Technological Independence in Africa: Solar Energy

Map of the World at Night

Map of Possibilities
Mpala Project-Based Module

- 49,107 acres of savannah and dry woodland, 1 hour from Nanyuki, on the Laikipia Plateau in North Central Kenya
- MRC staff members and immediate families housed in various community villages
  - Homes were generally a single 20-ft diameter room. People used old bed-sheets to partition the space to create a living room and 1-2 bedrooms. Household sizes ranged from 1-8 persons.
- Because it is in a remote area, access to basic necessities is a challenge.
  - Clean drinking water is available to staff and researchers through boreholes and purified rainwater collection.
  - Electricity, however, is only provided to the research community, through a combination of solar panels and generators
Rural Life inMpala Village
Types of lighting and energy sources
Solar Lanterns:

- 28-pc LED light
- 6V Battery
- 9V Solar Panel
- 6V AC Charger
- Universal charger for mobile phone batteries
Community-Based Solar Power Implementation

- One 85W panel in each:
  - Ranchhouse village
  - Research Center village
Solar-Powered Vaccine Delivery System for Medical Clinics in Rural Communities
Hybrid Wind and Solar Energy Harvesting System
Equipment Needed for Implementation

- Materials modules need same set-up and assessment as the other NJCTL PSI-PMI modules
- However project-based modules need the following:
  - Clean Water Project
    - Clay and saw dust
    - Metallic mold for pressing filters
    - Clay filters
    - 3M E.Coli counting paper
  - Clean Energy
    - Kerosene Lantern
    - 1-2 W solar panel
    - 6V battery and electrical wires
    - Bamboo and natural fibers e.g. sisal
Summary & Concluding Remarks

• This class presents an overview of the materials science modules that are part of the MS4SSA program.

• The teaching modules present an introduction to materials science and engineering – structure, properties, processing, materials selection & design.

• They enable a more intuitive approach to learning how to use the materials around us for different functions.

• The teaching modules are complemented with project-based approaches that teach “problem solving” and engineering within an African/global context.

• We welcome your engagement in using human capacity in materials science and engineering as engines for African development...
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