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

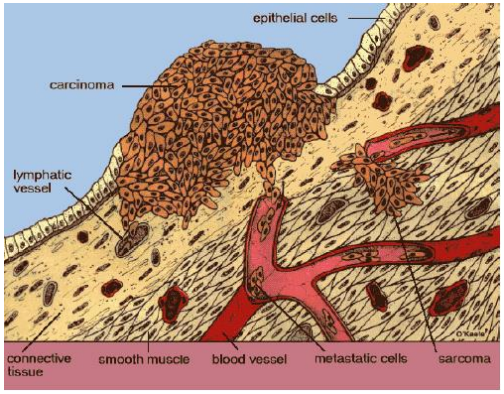
- Science and technology are the major engines of development
- Materials have always been a major driver in technological change…
  - Alloys
  - Semiconductors
  - Polymers
  - …

Hard materials

Soft materials

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



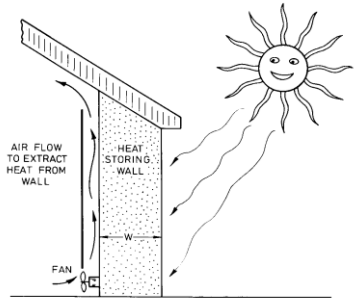
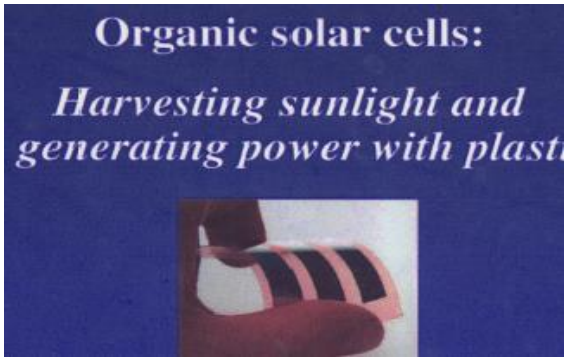
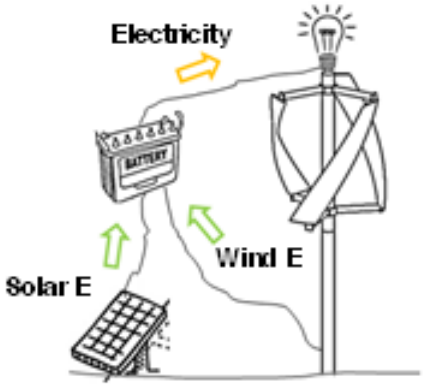


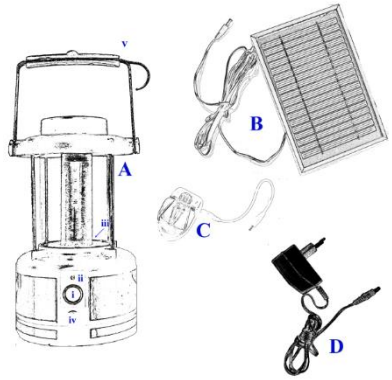
FIG. 6.32 A heat-storing wall. The sun shines on the outside during the day; heat is extracted from the inside at night. The heat diffusion time through the wall must be about 12 hours.



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

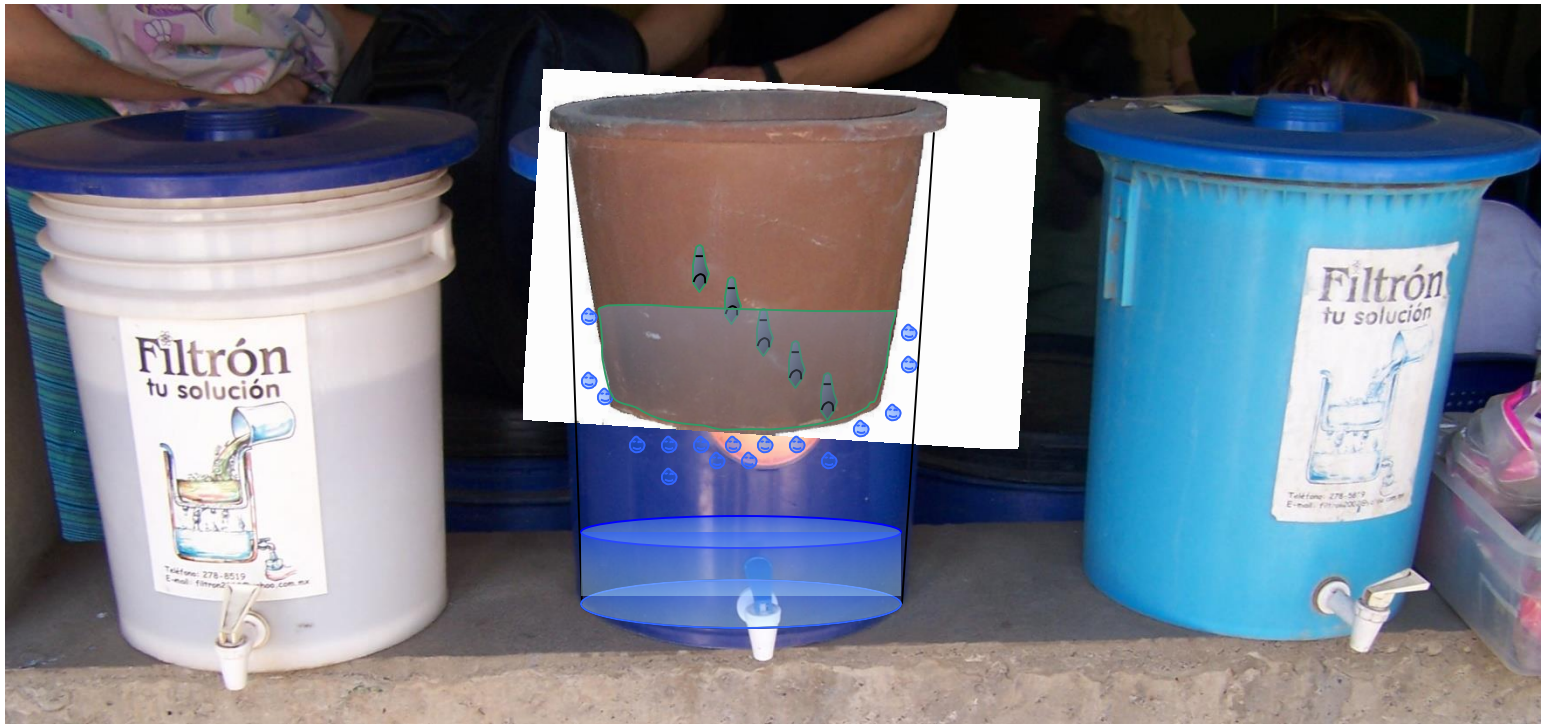
Background and Introduction to Clean Water Project

- 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

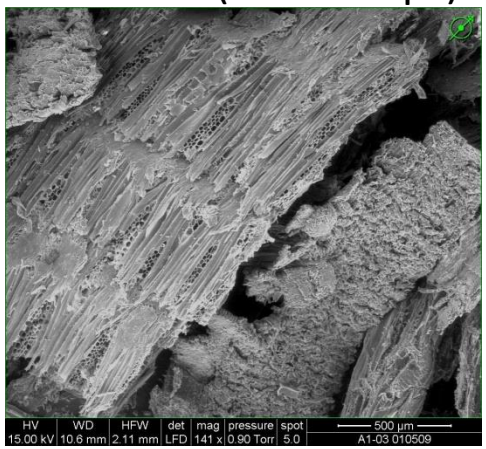
Solutions	Pros	Cons
Boiling Water	- 100% potable if boiled for at least 20 min. - Can be done in the home all year round.	- Requires time to gather fuel (fire wood) - Requires time for heating and cooling - Causes a Change in the taste of water - Method does not remove turbidity
Adding Chlorine	-Effectively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

Point-of-Use Water Filtration Systems

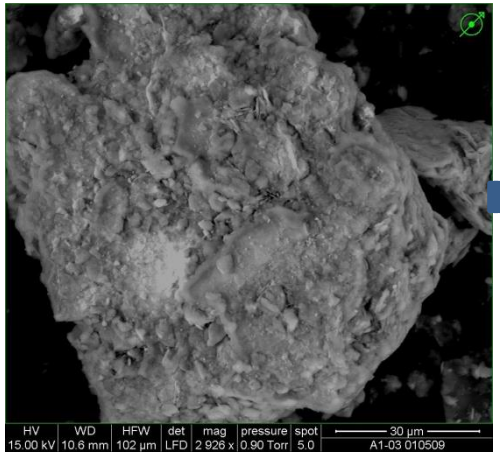


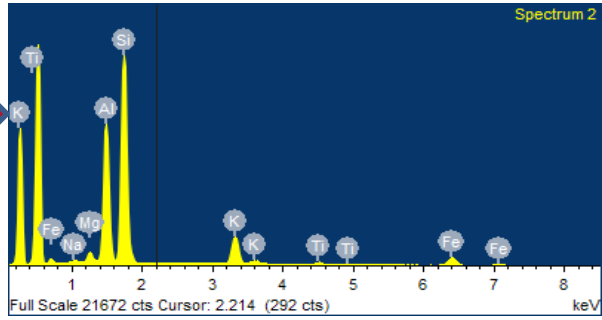
Materials Science: Surface Morphology and Chemical Composition - SEM/EDX

Sawdust (Woodchips)

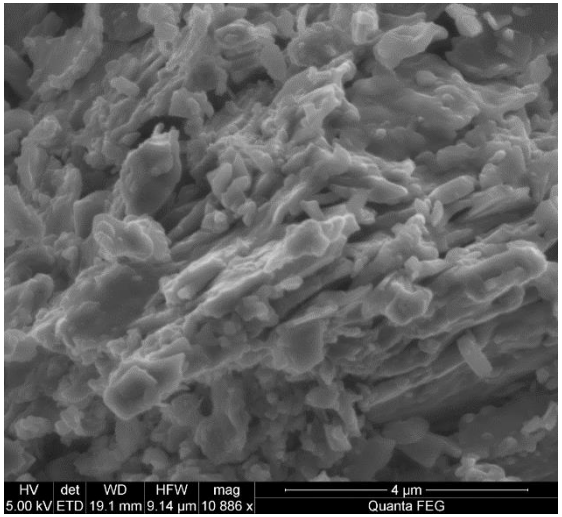


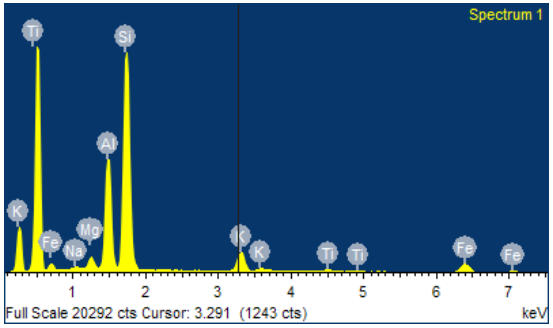
Clay (Redart)

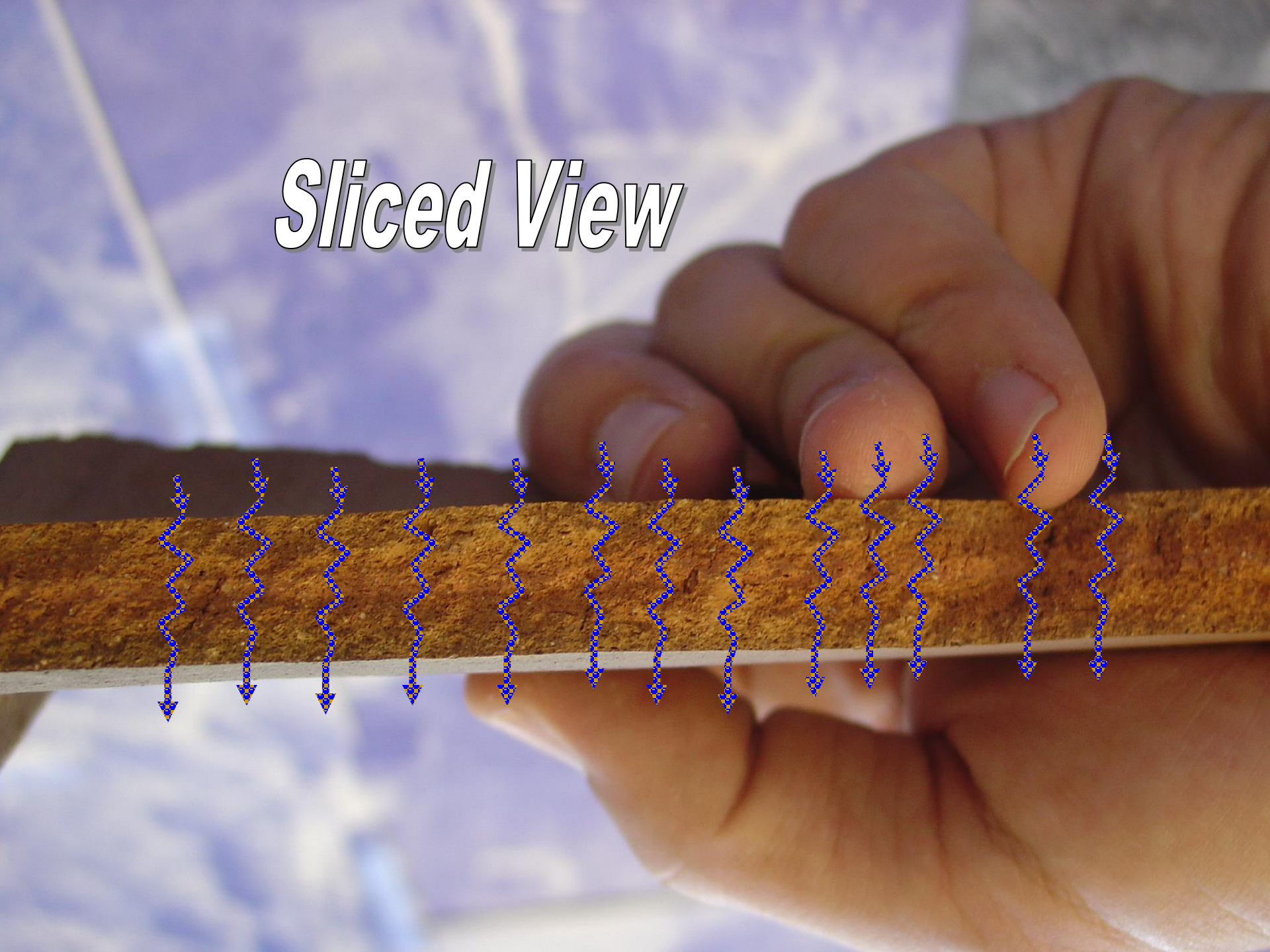




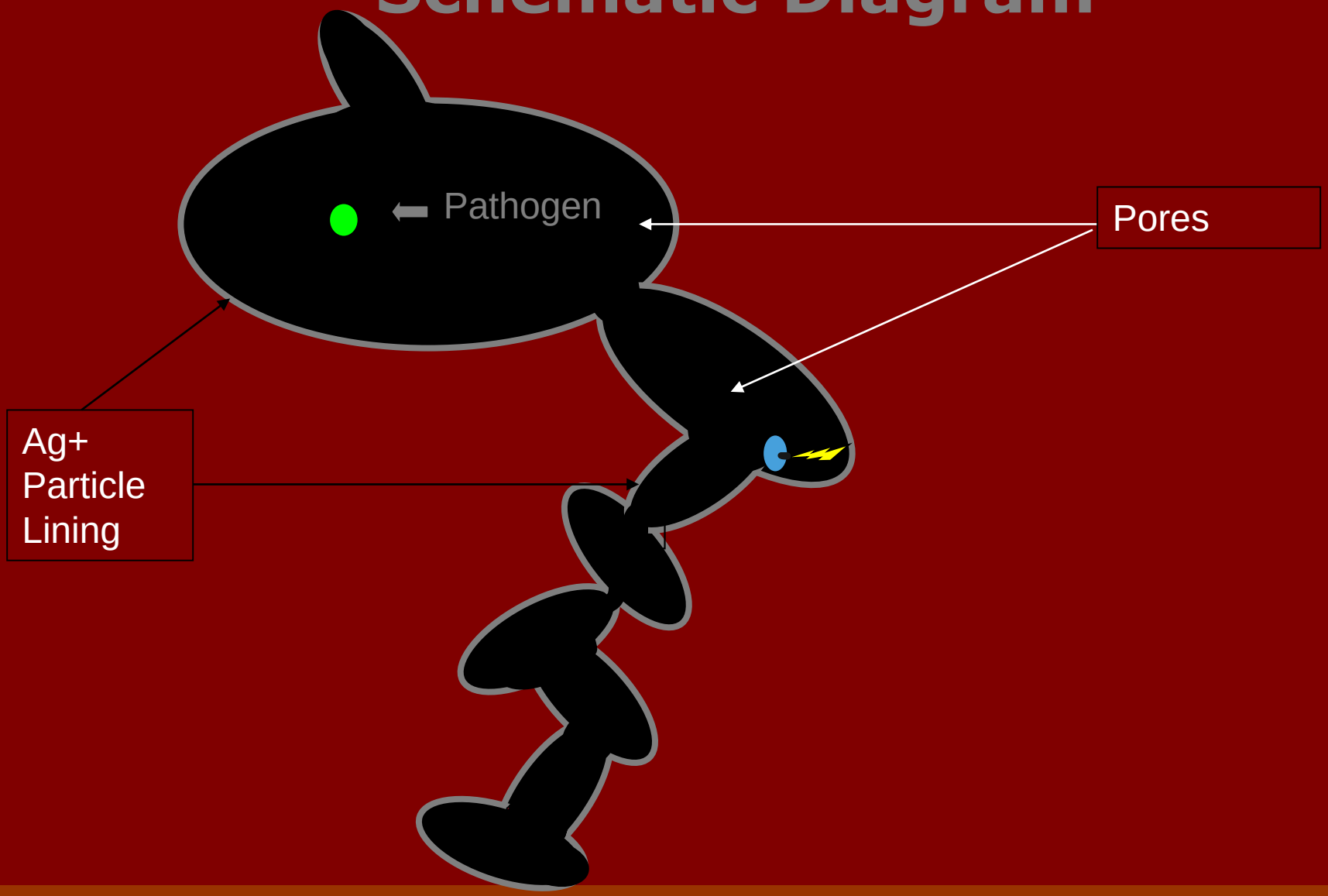
Porous Ceramic






Sliced View

Schematic Diagram



Size Comparison

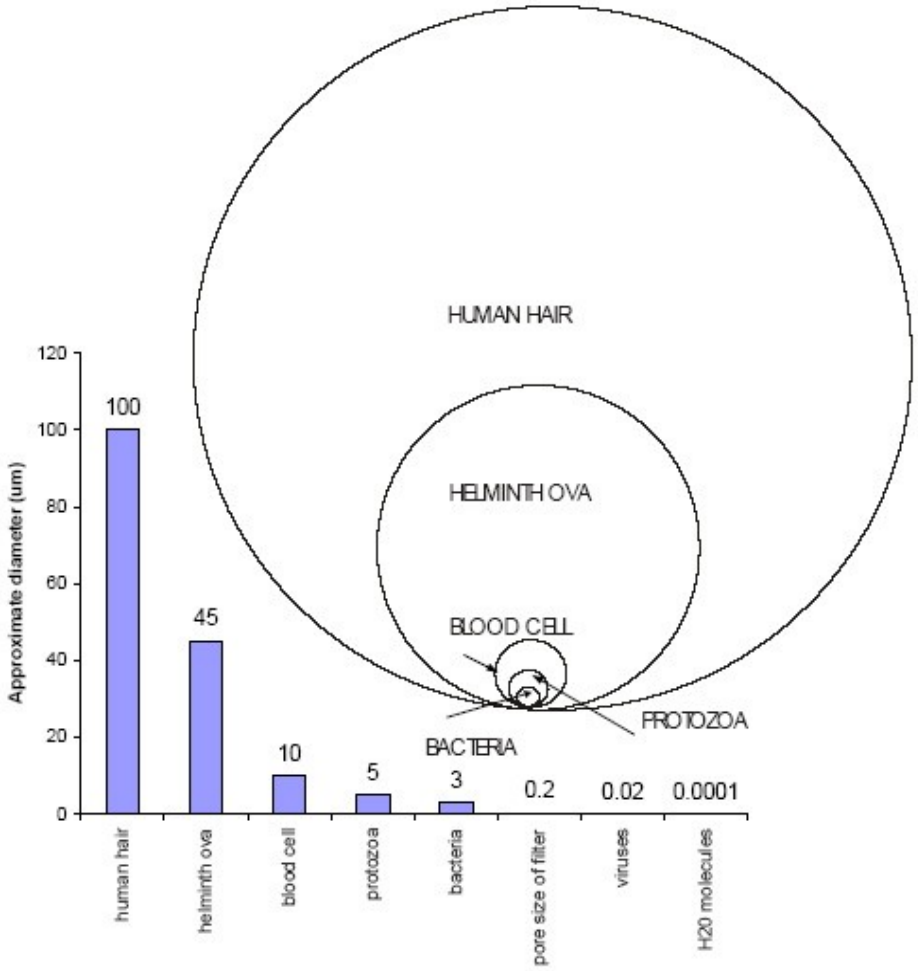
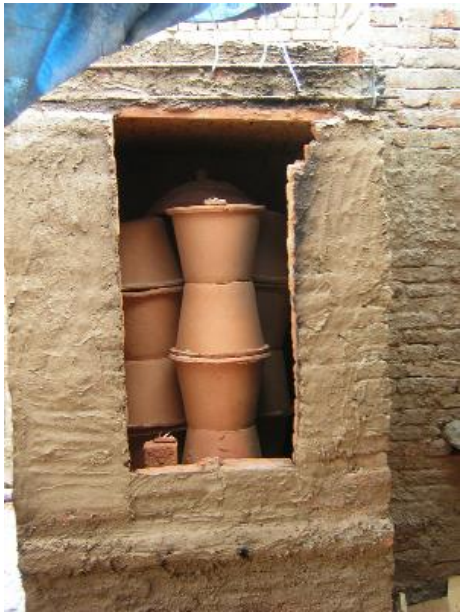


Figure 2. Comparison of relative sizes of various contaminants in water. Based on these, the pore size of the ceramic filter, at 0.2μm, would be about the size of a full stop on this page.

E. coli Filtration Tests of Non-Coated Ceramic Water Filters

Volume Fraction Clay:Sawdust	Test 1	Test 2	Average ± Range
45:55	99.97	99.85	99.91 ± 0.06
50:50	99.99	99.93	99.96 ± 0.03
55:45	99.52	99.84	99.68 ± 0.16
65:35	99.99	99.99	99.99 ± 0.00

Filter Processing - From Ideas to Markets



Project-Based Module on Clean Energy

Project-Based Approach

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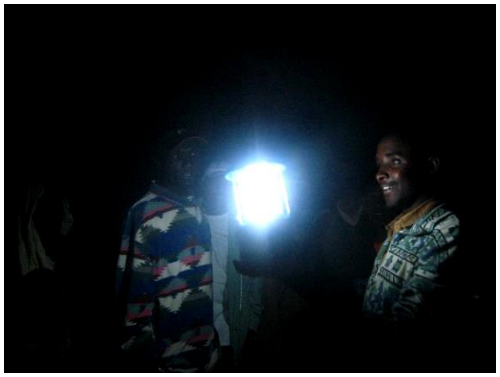
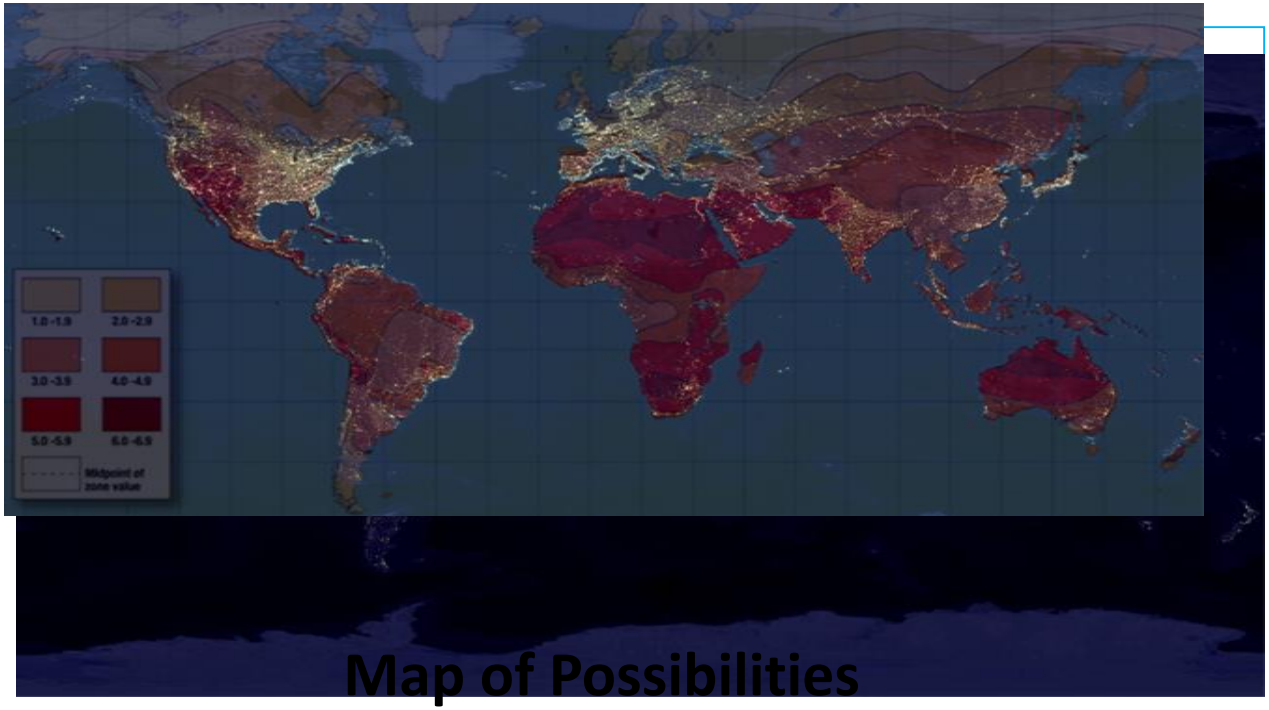
From Problem to Solution



Motivating Technological Independence in Africa: Solar Energy



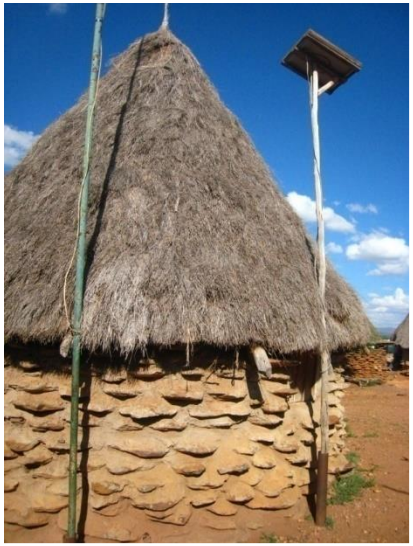
Map of the World at Night

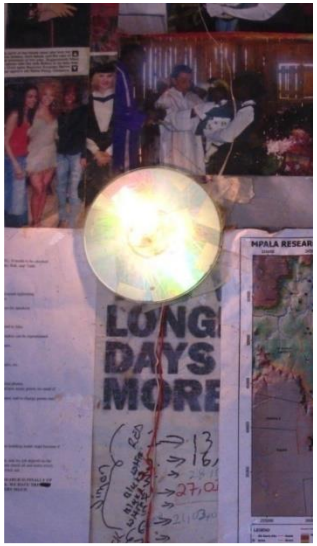
Mpala Project-Based Module

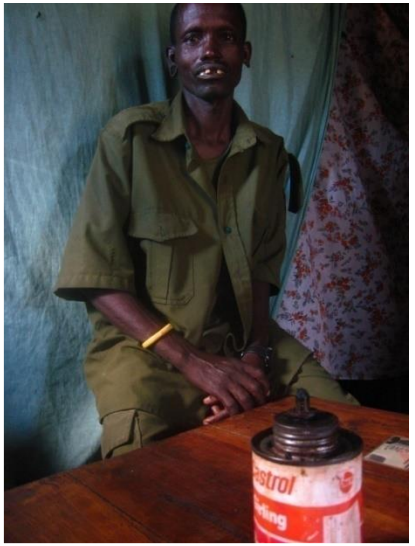
- 49,107 acres of savannah and dry woodland, 1 hour from Nanyuki, on the Laikipia Plateau in North Central Kenya
- MRC staff members and immediate families housed in various community villages
  - Homes were generally a single 20-ft diameter room. People used old bed-sheets to partition the space to 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 in Mpala Village

Types of lighting and energy sources

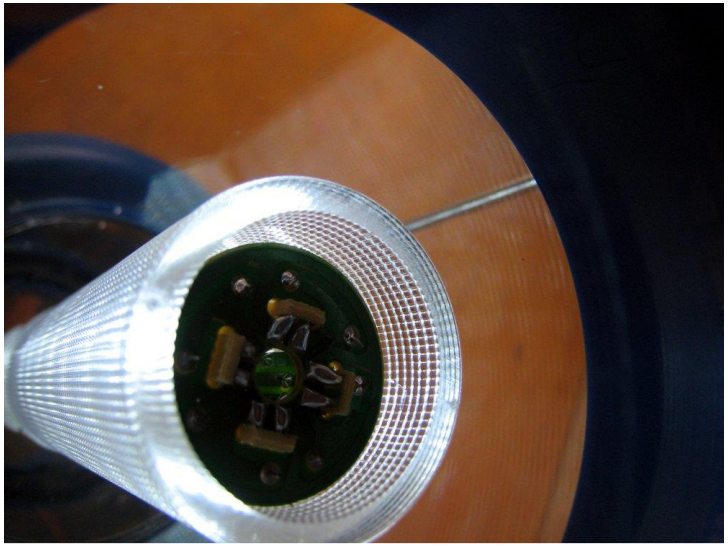


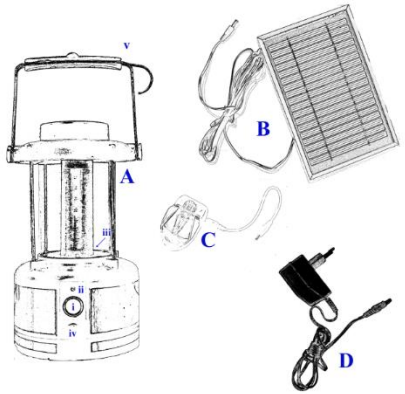




Solar Lanterns:

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

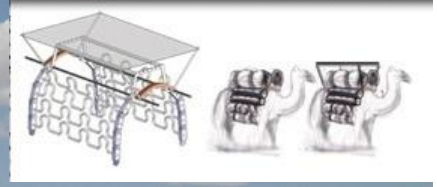




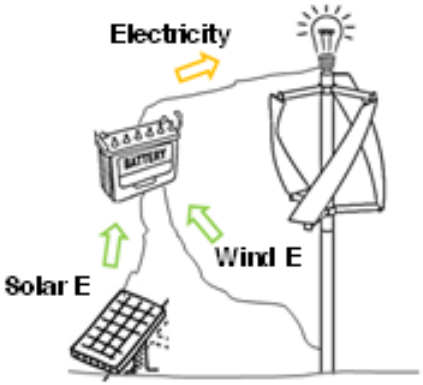
Community-Based Solar Power Implementation

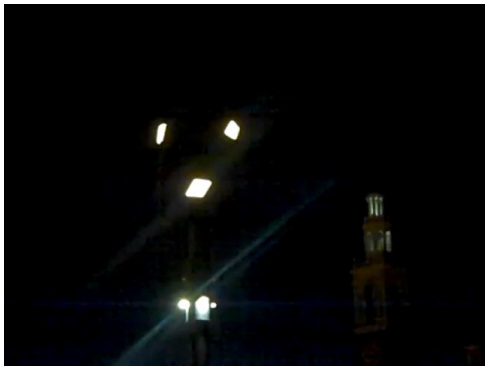
- One 85W panel in each:
  - Ranchhouse village
  - Research Center village

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...

Acknowledgements

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THANK YOU!
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