The Microbiology of Solar Water Pasteurization, with Applications in East Africa

Robert Metcalf
Professor, Biological Sciences
California State University, Sacramento

For children in developing countries, each year contaminated water causes:
2 million deaths
1.5 billion episodes of diarrhea

How can contaminated water be made safe to drink?

Milk Pasteurization

71.7°C (161°F)
15 Seconds

Pasteurization of whole eggs

60°C (140°F)

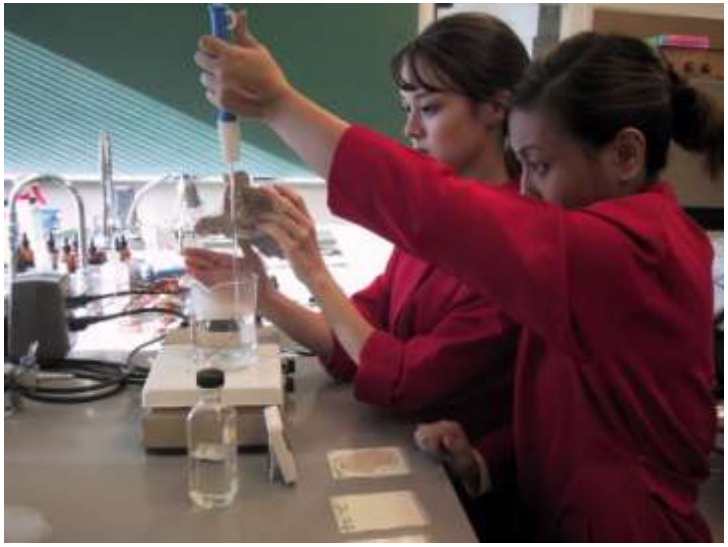
3.5 min

D - Value
(Decimal Reduction Time)

Time to cause 90% kill at a given temperature

Temperatures which kill pathogens in contaminated water

Microbe	D value < 1 min
Giardia, Cryptosporidium	55°C
E. coli, cholera, typhoid, Shigella bacteria, rotavirus	*60°C*
Hepatitis A virus	*65°C*




65.0
Tendicator 400 Type T/°C
0208
nuova II
STIR PLATE
HEAT
STIR


T-19 1min 5/8/04
60°
TNTC
T-19 2min 5/8/04
60°
89
T-19 3min 5/8/04
60°
1
T-19 1min 5/8/04
62°
77
T-19 2min 5/8/04
62°
1
T-19 3min 5/8/04
62°
0
T-19 1min 5/8/04
65°
0
T-19 2min 5/8/04
65°
0
T-19 3min 5/8/04
65°
0

D value, *E. coli* in water

60°C	40 seconds
62°C	25 seconds
65°C	10 seconds

Solar Water Pasteurization

Heating water to 65°C (149°F) in a solar cooker will pasteurize the water and kill disease causing microbes

PPLIED AND ENVIRONMENTAL MICROBIOLOGY, Feb. 1984, p. 223–228
099-2240/84/020223-06$02.00/0

Vol. 47, N

Pasteurization of Naturally Contaminated Water with Solar Energy

DAVID A. CIOCHETTI † AND ROBERT H. METCALF*

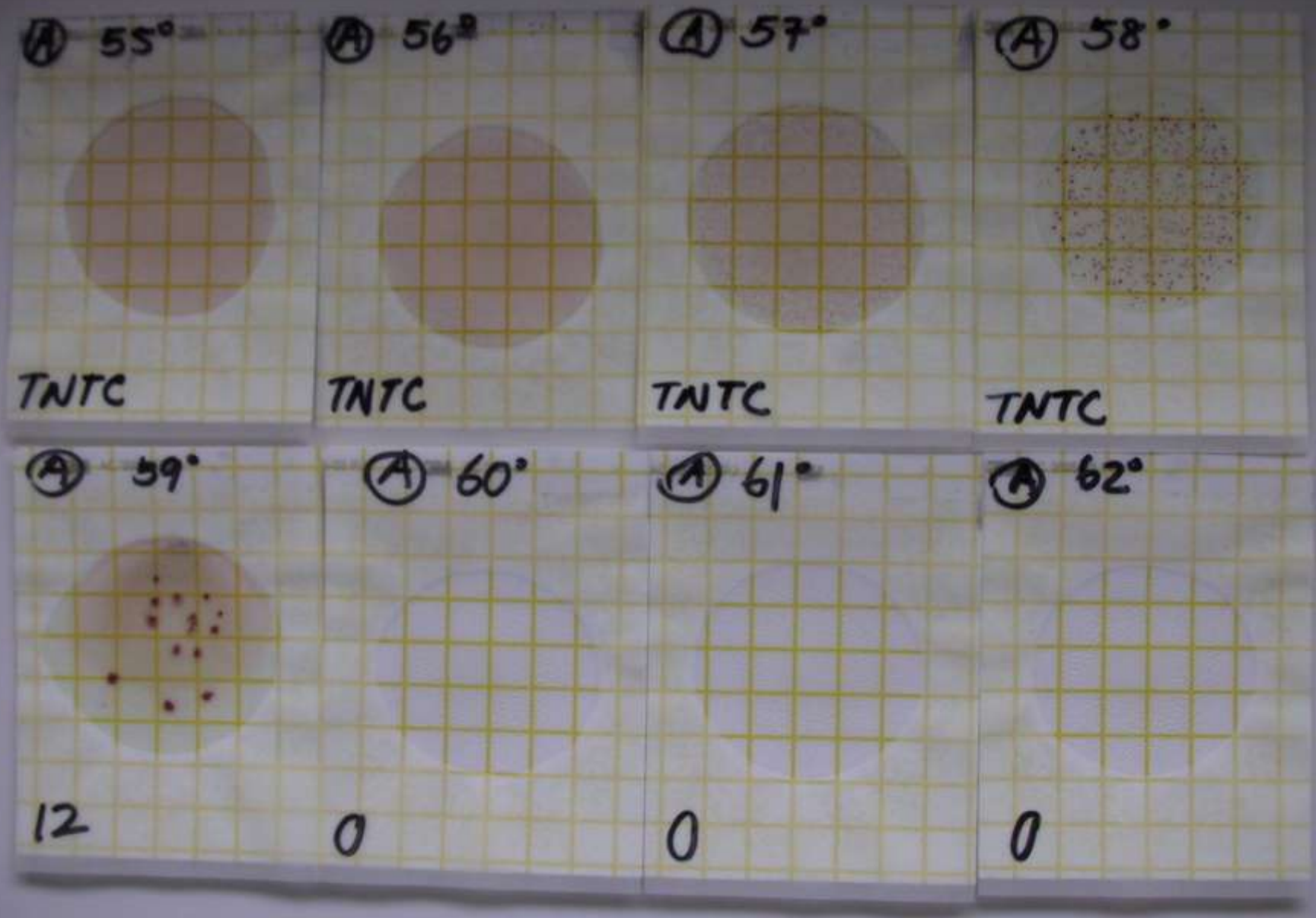
Department of Biological Sciences, California State University, Sacramento, Sacramento, California 95819

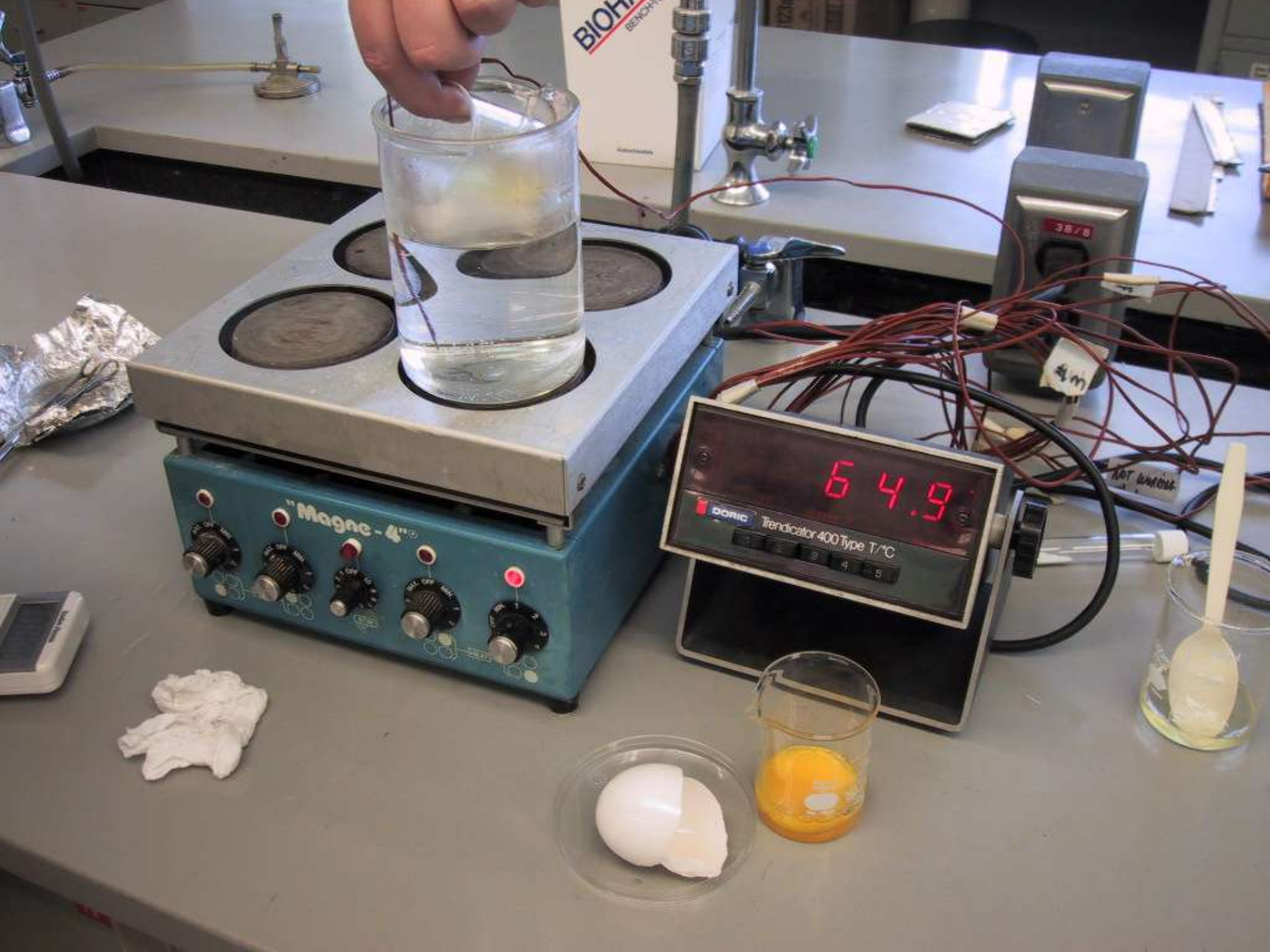
Received 25 July 1983/Accepted 7 November 1983

A solar box cooker (SBC) was constructed with a cooking area deep enough to hold several 3.7-liter jugs of water, and this was used to investigate the potential of using solar energy to pasteurize naturally contaminated water. When river water was heated either in the SBC or on a hot plate, coliform bacteria were inactivated at temperatures of 60°C or greater. Heating water in an SBC to at least 65°C ensures that the water will be above the milk pasteurization temperature of 62.8°C for at least an hour, which appears sufficient to pasteurize contaminated water. On clear or partly cloudy days, with the SBC facing magnetic south in Sacramento, bottom water temperatures of at least 65°C could be obtained in 11.1 liters of water during the 6 weeks on either side of the summer solstice, in 7.4 liters of water from mid-March through mid-September, and in 3.7 liters of water an additional 2 to 3 weeks at the beginning and end of the solar season. Periodic repositioning of the SBC towards the sun, adjusting the back reflective lid, and preheating water in a simple reflective device increased final water temperatures. Simultaneous cooking and heating water to pasteurizing temperatures was possible. Additional uses of the SBC to pasteurize soil and to decontaminate hospital materials before disposal in remote areas are suggested.

Several attempts have been made to use the energy of the un and solar cookers to cook and bake food. The two most ommon solar cooker designs are the slant-faced cooker ith side reflectors and the antenna dish concentrator. hese solar cookers have proven to be impractical for egular cooking and baking because their poor designs allow

found that several liters of river water in 4-liter cooking p could be heated to 80°C or greater in 2 h in an SBC, killing coliform and fecal coliform bacteria (M. Logvin, M thesis, California State University, Sacramento, 1980). wanted to expand on this particular use of an SBC, and t we built an SBC which was deep enough to hold three to f


A 55°
TNTC
A 56°
TNTC
A 57°
TNTC
A 58°
TNTC
A 59°
12
A 60°
0
A 61°
0
A 62°
0


"Magnc - 4"
64.9
DORIC
Trendicator 400 Type T/°C


Radio Shack
TMR
M
S
0031
1 2 3 4 5
6 7 8 9 0
START
STOP / RESET


Radio Shack
TMR
M
S
0 100
1 2 3 4 5
6 7 8 9 0
START
STOP / RESET

How can one verify that water has been heated to 65°C?

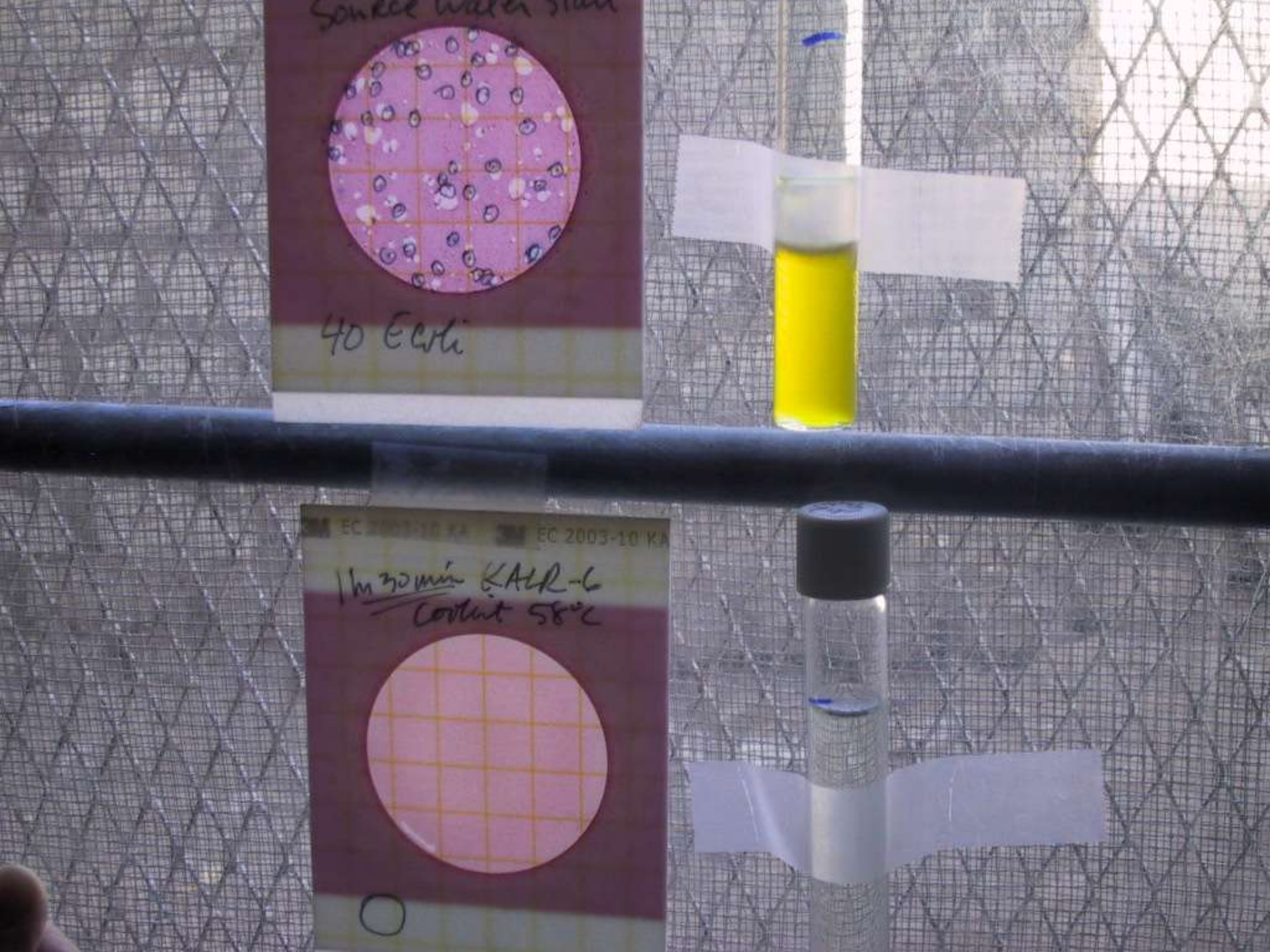
Water Pasteurization Indicator (WAPI)

Temperatures which kill disease microbes present in contaminated water

MICROBE	KILLED RAPIDLY AT:
Worms, *Giardia*, *Entamoeba*, *Cryptosporidium*	131□F (55□C)
Escherichia coli, *Shigella*, cholera, Typhoid, Rotaviruses, Polioviruses	140□F (60□C)
Hepatitis A virus	149□F (65□C)
WAPI wax melts	**149□F (65□C)**


Coca-Cola
KALANDO
BAR
STOP
DRINK
enjoy
Coca-Cola
THE MIDDLE KALANDOS LODGE


SOLAR COOKER
63.8
38.9


40 EColi
EC 2003-10 KA
EC 2003-10 KA
1h 30 min KALR-6
Count 58°C

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Feb. 1999, p. 859–861 Vol. 65, No. 2
0099-2240/99/$04.00+0

Enhancement of Solar Water Pasteurization with Reflectors

NEGAR SAFAPOUR† AND ROBERT H. METCALF*

Department of Biological Sciences, California State University Sacramento, Sacramento, California 95819-6077

Received 13 July 1998/Accepted 3 November 1998

A simple and reliable method that could be used in developing countries to pasteurize milk and water with solar energy is described. A cardboard reflector directs sunshine onto a black jar, heating water to pasteurizing temperatures in several hours. A reusable water pasteurization indicator verifies that pasteurization temperatures have been reached.

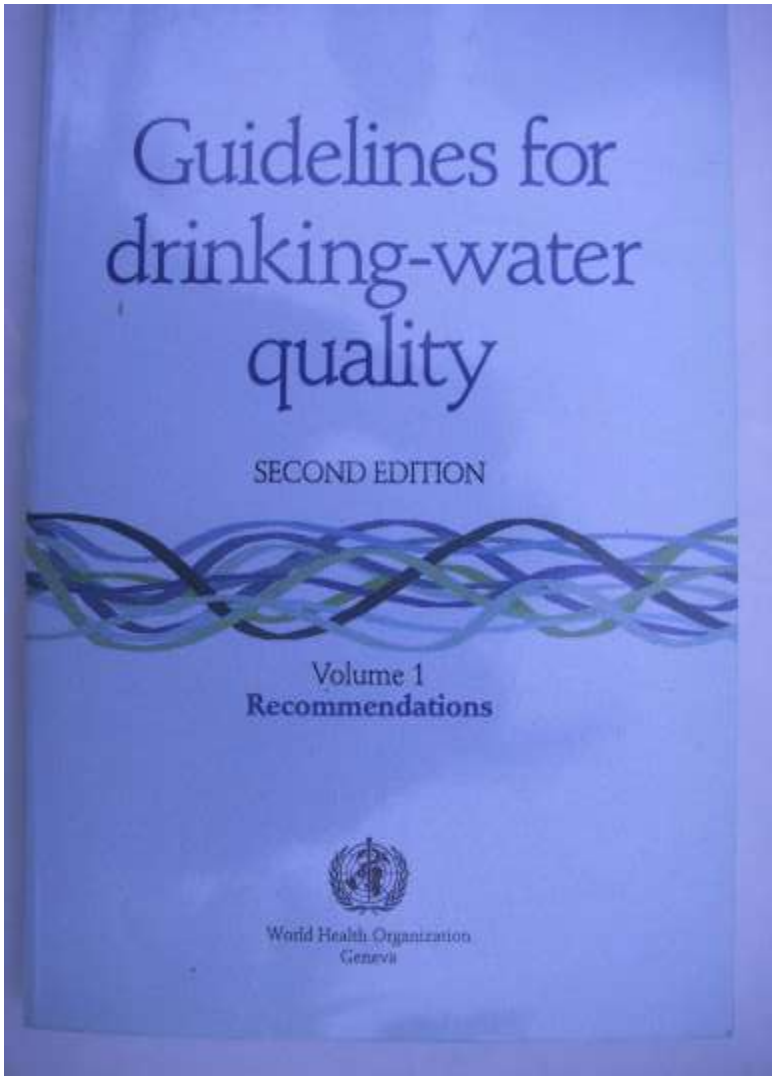
Exposing water in clear plastic or glass jars to sunshine has been shown to inactivate bacteria. However, much variability–from no inactivation to an approximately 3-log decrease in 1.5 h–has been reported (1, 2, 10–12, 14, 15, 17, 18, 20). Reasons for this variability include the transparency of the container, water turbidity, water temperature reached, altitude, aerobic or anaerobic conditions, and the amount of solar radiation received (2, 10–12, 15, 17). In addition, only a few studies have included viruses or protozoan cysts, which might not be as sensitive to sunshine as bacteria.

A major limitation of exposing clear containers of water to sunshine is that there is no simple test to perform which would tube, it indicates that pasteurization conditions have been reached.

The bacteriophage T2 was included in these studies. Although T2 is not a human pathogen, its inclusion tests the validity of extrapolating to nonbacterial microbes *Escherichia coli*'s response.

Cultures and test conditions. *E. coli* ATCC 11775 (American Type Culture Collection, Rockville, Md.) was maintained in brain heart infusion broth (BHI; Acumedia, Baltimore, Md.). A stock of T2 phage with 4×10^9 PFU/ml was obtained by seeding 100 ml of BHI broth with *E. coli B* and a drop of T2 and incubating at 35°C for 12 h when complete lysis was ob-

Point Source Water Testing in Developing Countries



- **The most specific of the readily detectable fecal indicators, and the one present in greatest numbers in feces, is *Escherichia coli*, and *it is therefore recommended as the indicator of choice for drinking water*.**


INDICATOR of
Escherich
Professor
Metcalf


STAND-UP BAG WHIRL-PAK STAND-UP BAG
4 OZ. FILL LINE
4 OZ. FILL LINE
100ml FILL LINE
100ml FILL LINE
Nasco WHIRL-PAK
SPECTROLINE® UV-4B Ultraviolet Lamp
SPECTRONICS


3M
Petrifilm™
E. coli/Colifor Count Plate
Test pour la r mération des E. coli et des Coliformes
Test zum Nac weis von E. coli und Coliformen
Piastra per il nteggio de E. coli e coliformi
Placas para R cuento de E. coli y Coliformes
E. coli en coli ormen telplaat
Odlingsplatta för E. coli och koliforma bakterier
E. colin ja ko formien laskenta-alusta
Placa para C ntagem de E. coli e Coliformes
25
STAND-UP BAG WHIRL-PAK STAND-UP BAG WHIRL-

Colilert®

An easy 24-hour test for coliforms and *E. coli*

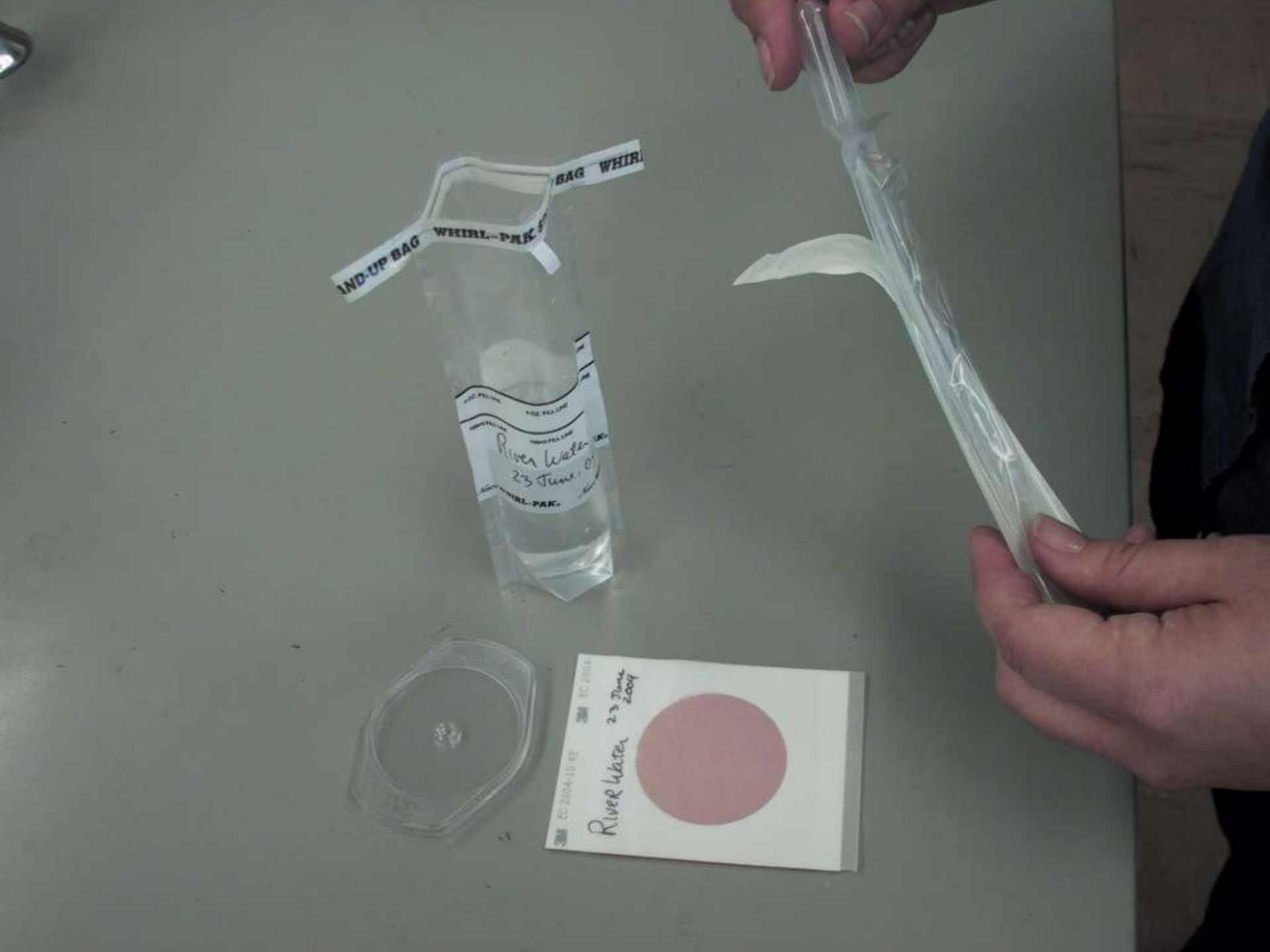
Colilert has become the number one method in countries around the world because:

- Colilert takes less than one minute hands-on time per sample.
- Colilert is approved internationally for compliance testing.
- Colilert has been shown to be 20–50% less expensive than traditional methods[1].

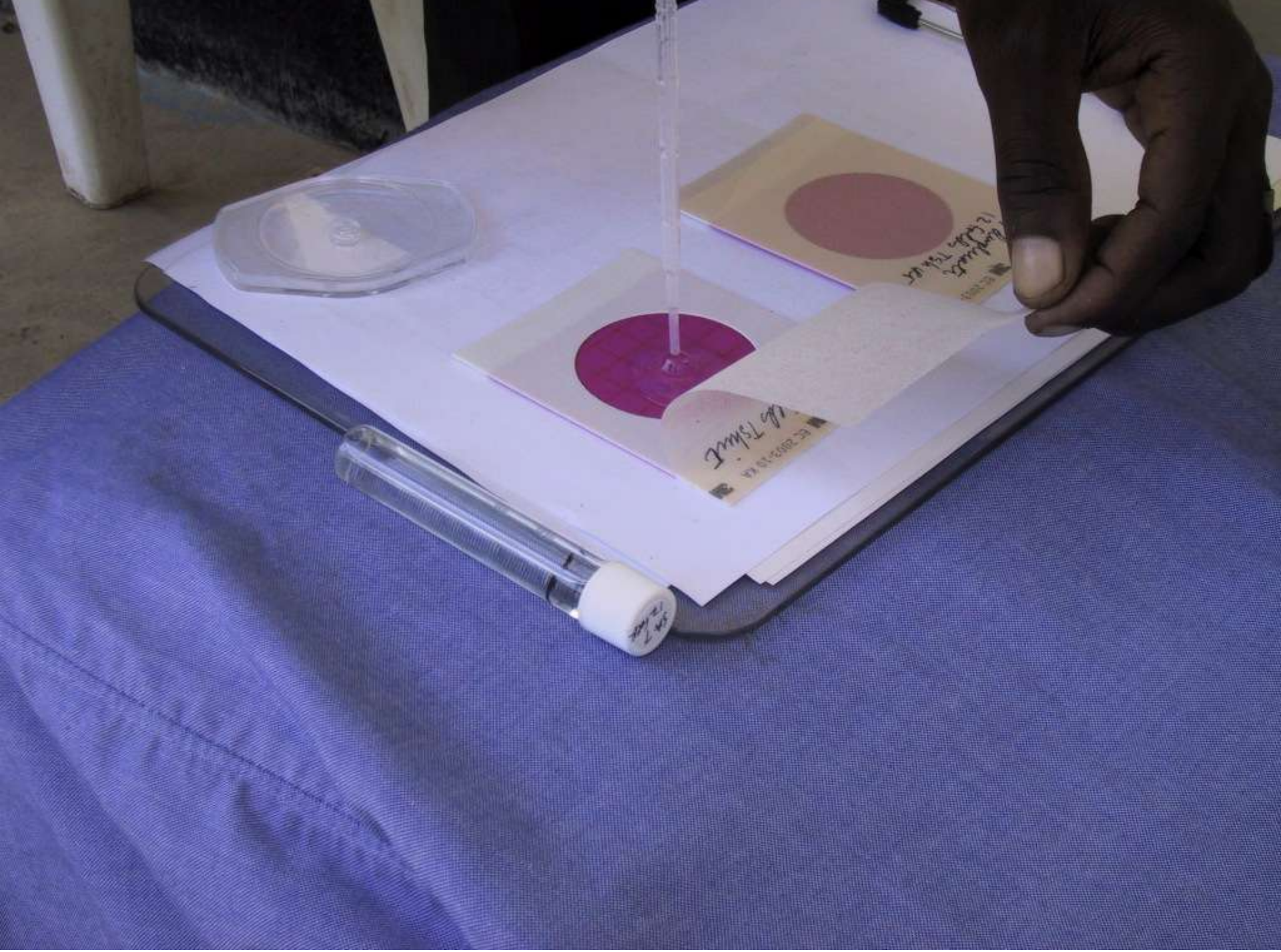
3M

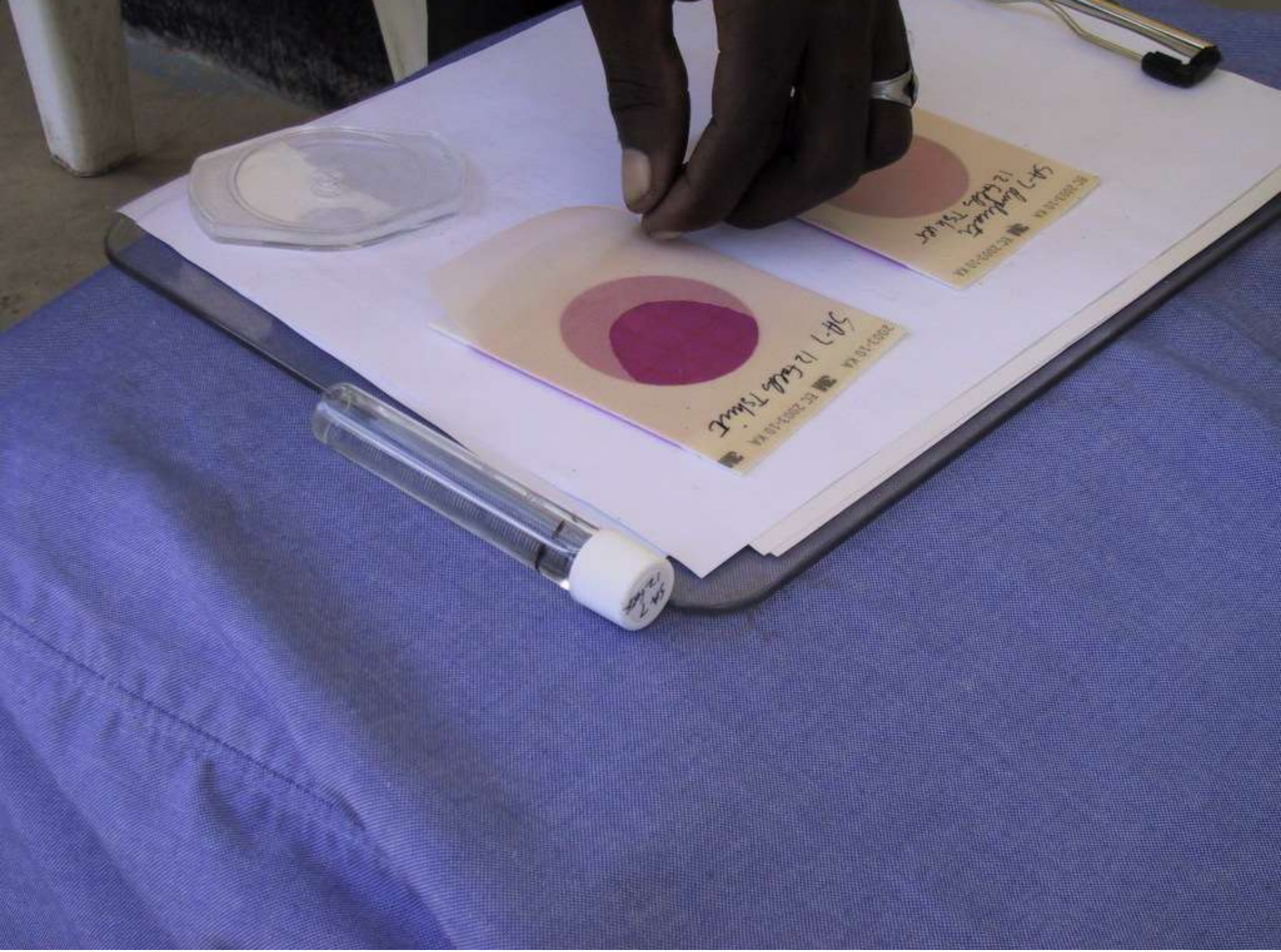
Petrifilm™ E. coli/Coliform Count Plates

Easiest and fastest confirmed E. coli test available.

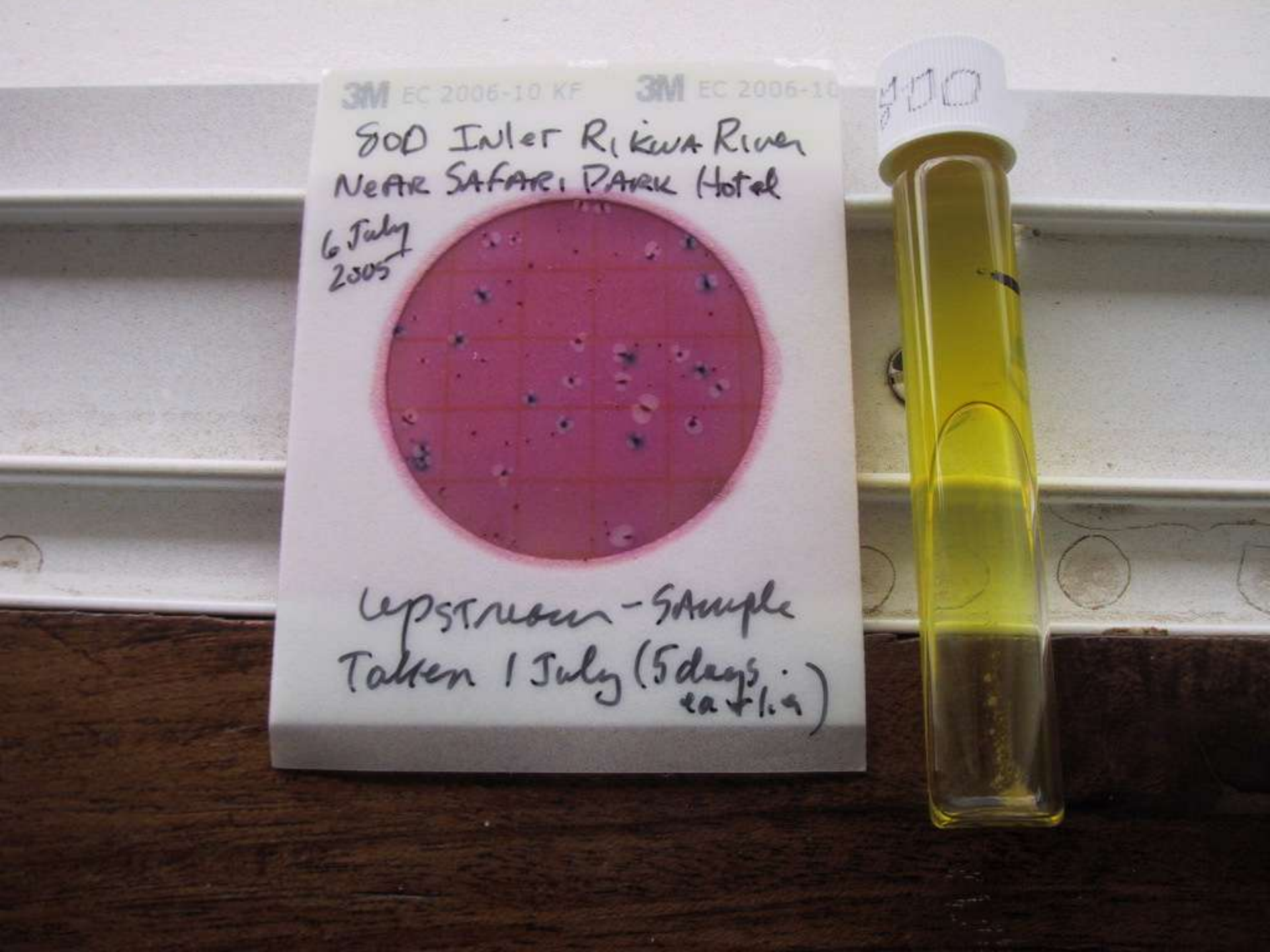

BAG WHIRL
WHIRL-PAK
River water
23 June, 04
WHIRL-PAK
River water
23 June 2004

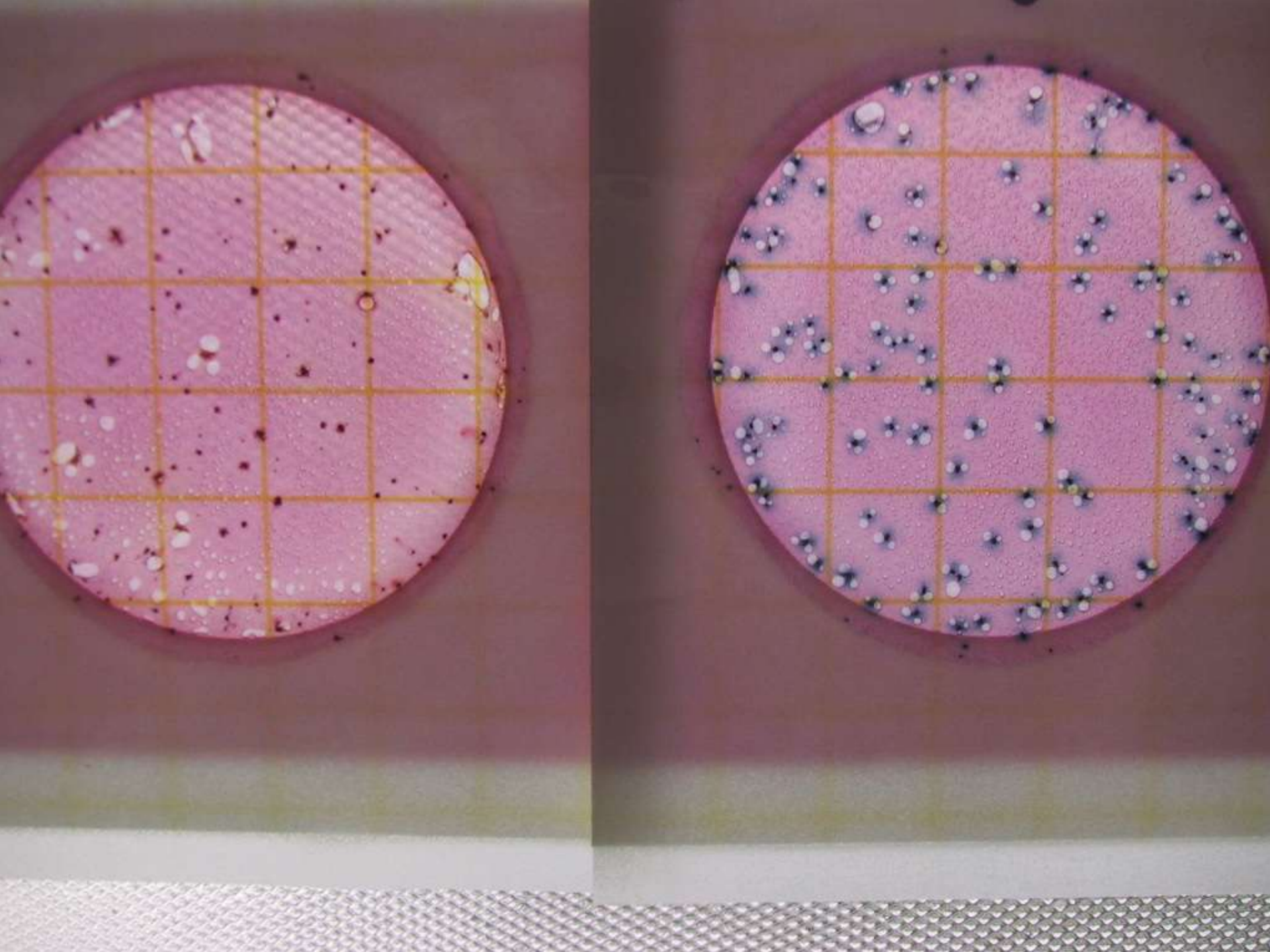

HACH
OPERATIONAL GUIDE





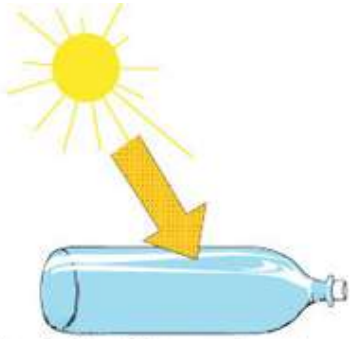

EC 2003-10 KA
3M
EC 2003-10 KA
SA-7 duplicate
12 folds Tshirt
1314
2003-10 KA
3M
EC 2003-10 KA
SA-7 12 folds Tshirt


3M EC 2006-10 KF
3M EC 2006-10
SOD INLET RIKWA RIVER
NEAR SAFARI PARK HOTEL
6 July 2005
LEPTOMON - SAMPLE
TAKEN 1 JULY (5 days ea + 1.9)



Risk Assessment of Water Sources

Risk Level	E. coli/sample	Colilert MUG	#Blue/Petrifilm
Low	**< 1/10 ml**	**-**	**0**
Moderate	**1-9/10 ml**	**+**	**0**
High	**1-10/ml**	**+**	**1-10**
Very High	**> 10/ml**	**+**	**> 10**

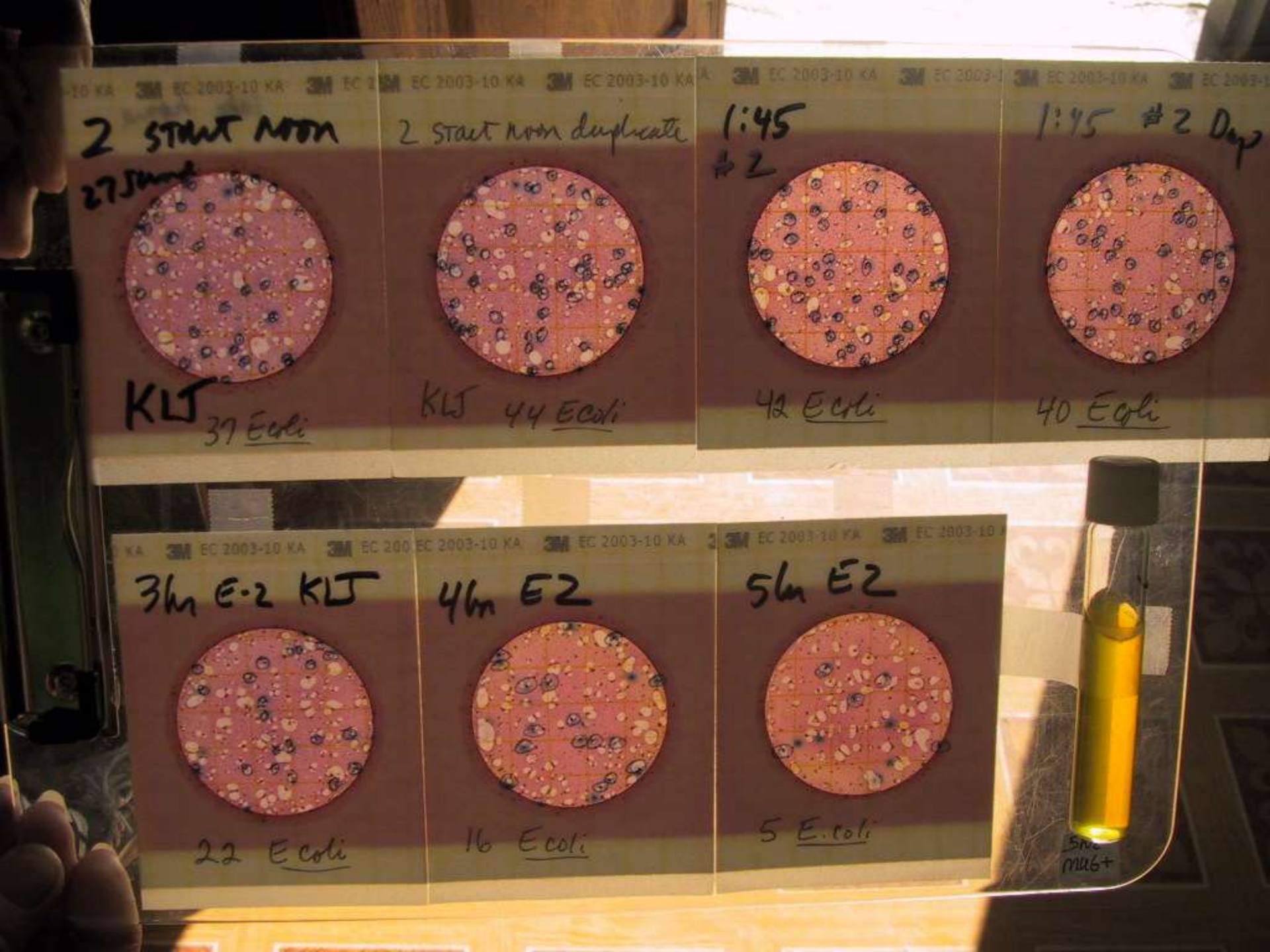


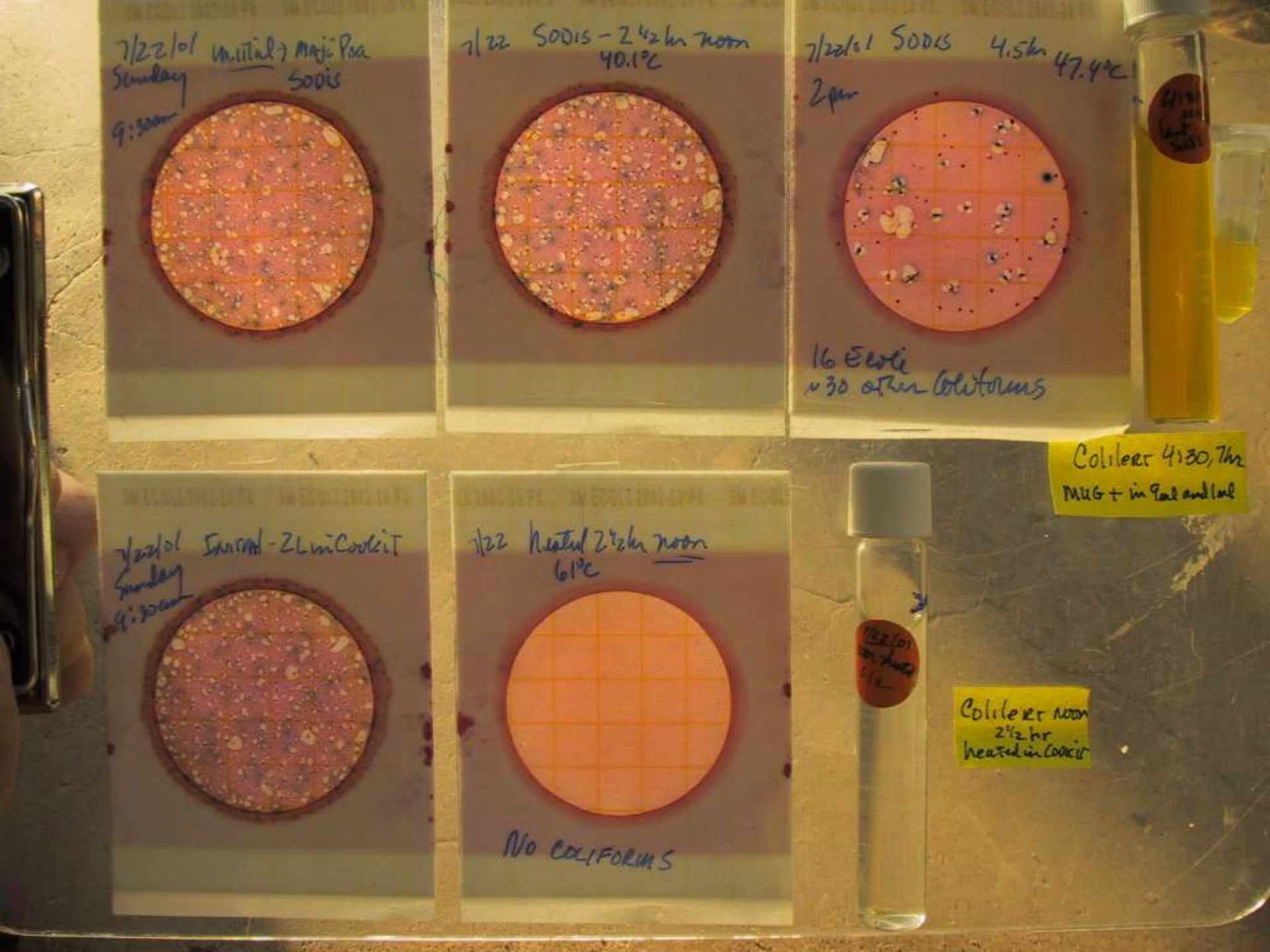
Inactivation of microorganisms by UV-A-radiation and thermal treatment

- The Solar Water Disinfection (SODIS) process is a simple technology used to improve the microbiological quality of drinking water. SODIS uses solar radiation to destroy pathogenic microorganisms which cause water borne diseases.

- SODIS is ideal to treat small quantities of water. Contaminated water is filled into transparent plastic bottles and exposed to full sunlight for six hours.

- Sunlight is treating the contaminated water through two synergetic mechanisms: **Radiation** in the spectrum of **UV-A** (wavelength 320-400nm) and **increased water temperature**. If the water temperatures raises above 50°C, the disinfection process is three times faster.


2 START NOON
KLJ 37 Ecoli
2 start noon duplicate
KLJ 44 Ecoli
1:45 #2
42 Ecoli
1:45 #2 Dup
40 Ecoli
3hr E-2 KLJ
22 Ecoli
4hr E2
16 Ecoli
5hr E2
5 E.coli


7/22/01 Initial Majic Pond
Sunday SODIS
9:30am
7/22 SODIS - 2½ hr noon
40.1°C
7/22/01 SODIS 4.5hr 47.4°C
2pm
16 E coli
~30 other Coliforms
Colilert 4:30, 7hr
MUG + in 9ml and 1ml
7/22/01 Initial - 2L in Cookit
Sunday
9:30am
7/22 Heated 2½ hr noon
61°C
NO COLIFORMS
Colilert noon
2½ hr
heated in Cookit

Sunny Solutions Project

Nyakach Kenya


STOCKIST

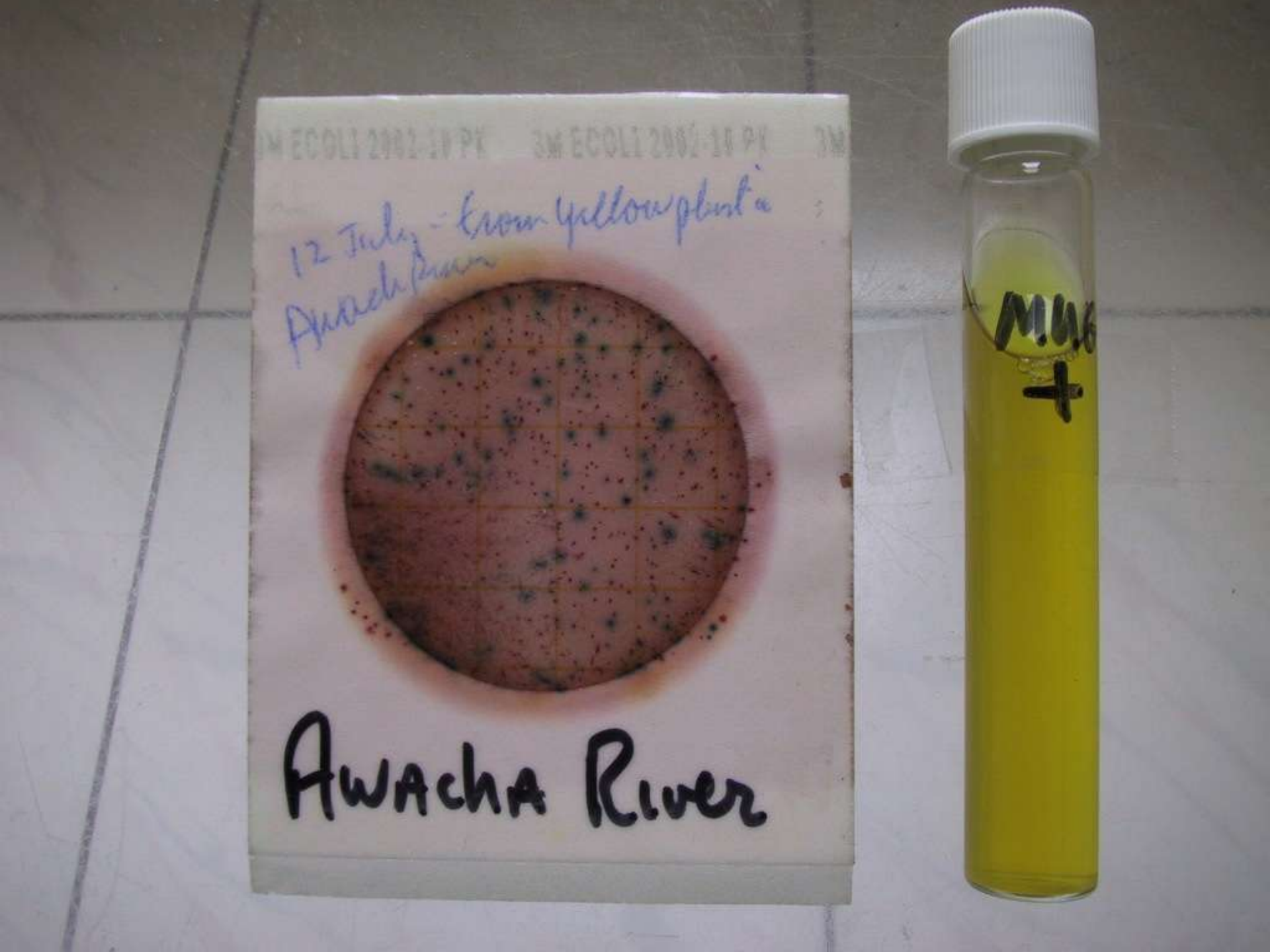

Water Sources from Kitito Workshop
Participants 21 July, 2003
7
8
9
10
11
12


7
8
9
10
11
12


Water Sources from Kitito Workshop
Participants 21 July, 2003
1
2
3
5
6


1
2
3
5
6


Omango Well
1430 7/7
28 E.coli
Omango Well
1430hrs 7/7
21 Ecoli
Omango Well
1430 7/7
29 Ecoli
Omango Well
1430 7/7
30 Ecoli
Omango Well
1430 7/7
33 Ecoli
MUG
+


12 July - from yellow plant
Awacha River
MUG
+


MINISTRY OF WATER AND IRRIGATIO
PROVINCIAL HEADQUARTERS
NYANZA PROVINCE
KISU/WD/1/1

Thermotolerant Coliform Test, Kenya

3 tube MPN, 10, 1, 0.1 ml

1. MacConkey's broth, 37°C, 1-2 days
2. Gas +to BGLB broth, 44°C, 1-2 days

   Gas + = Thermotolerant coliforms


3M


GA
RIVER
WATER


11A
Tap water
Nyabera


WATER RESOURCES MANAGEMENT AUTHORITY
WATER RESOURCES MANAGEMENT AUTHORITY
TANA CATCHMENT REGIONAL OFFICE
P. O. BOX 1930 EMBU TEL. 068- 31271
FAX 068- 31315 E-MAIL: wrmatana @ winnet·co·ke
SURVEY DEPT

WATER RESOURCES MANAGEMENT AUTHORITY

CERTIFICATE OF ATTENDANCE

This is to certify that

Bancy G. Chege

Attended the Training Workshop on Water Testing, Solar Water Pasteurization and Solar Cooking

Held at Farmers Training College Embu from 27th – 28th June, 2006.

Topics Covered:

- E. coli: An Indicator of Faecal Contamination of Water
- Principles of Defined Substrate Technology (DST)
- Bacterial Multiplication & Culturing
- Water Testing at community level: Demystifying μ-Biology
- Solar Water Pasteurization
- Use of Water Pasteurization Indicator (WAPI)
- Solar Cooking: A "Vaccine" against Deforestation

Prof. Robert Metcalf
California State University Sacramento

P. Oloo
CEO WRMA


Safaricom
1522


STAND-UP BAG WHIRL-PAK STAND-UP BAG
WHIRL-PAK
SPECTROLINE® UV-4B Ultraviolet Lamp


SUDAN
ETHIOPIA
UGANDA
SOMALIA
TANZANIA
Administrative Boundary
Kapoeta
Kelem
Negelē
Lokichokio
Kaabong
Lodwar
Moroto
Soroti
Mbale
Kitale
Tororo
Eldoret
Butere
Kakamega
Kisumu
Kericho
Nakuru
Nyahururu Falls
Nanyuki
Isiolo
Moyale
Marsabit
Mado Gashi
Wajir
Ramu
Dolo Odo
Garbahaarrey
Bilis Qooqaani
Garissa
Mount Kenya
Embu
Kindaruma dams
Thika
Narok
Nairobi
NAIROBI AREA
Magadi
Musoma
Lake Victoria
Lake Rudolf (Lake Turkana)
Lake Natron
Ch'ew Bahir
Kilimanjaro
Arusha
Moshi
Voi
Nyumba ya Mungu dam
Mombasa
Malindi
Lamu
Garsen
Pate Island
Pemba Island
Tanga
INDIAN OCEAN
RIFT VALLEY
EASTERN
NORTH EASTERN
WESTERN
NYANZA
CENTRAL
COAST
Kenya
International boundary
Province boundary
National capital
Province capital
Railroad
Road
0 50 100 Kilometers
0 50 100 Miles
Boundary representation is not necessarily authoritative.
Base 801062 (B00446) 1-88

Fuelwood = 79% of Kenya's Total Energy

Energy Usage Per Day

Wood = 81 million lbs

Charcoal = 13 million lbs


SCI SUNNY SOLUTIONS PROJECT OFFICE


2006
SAYE
2006
2006
2006
2006


PEMBE
MAIZE MEAL


SCOREPS

TEDI GI CHIENG'!
SOLAR COOK!

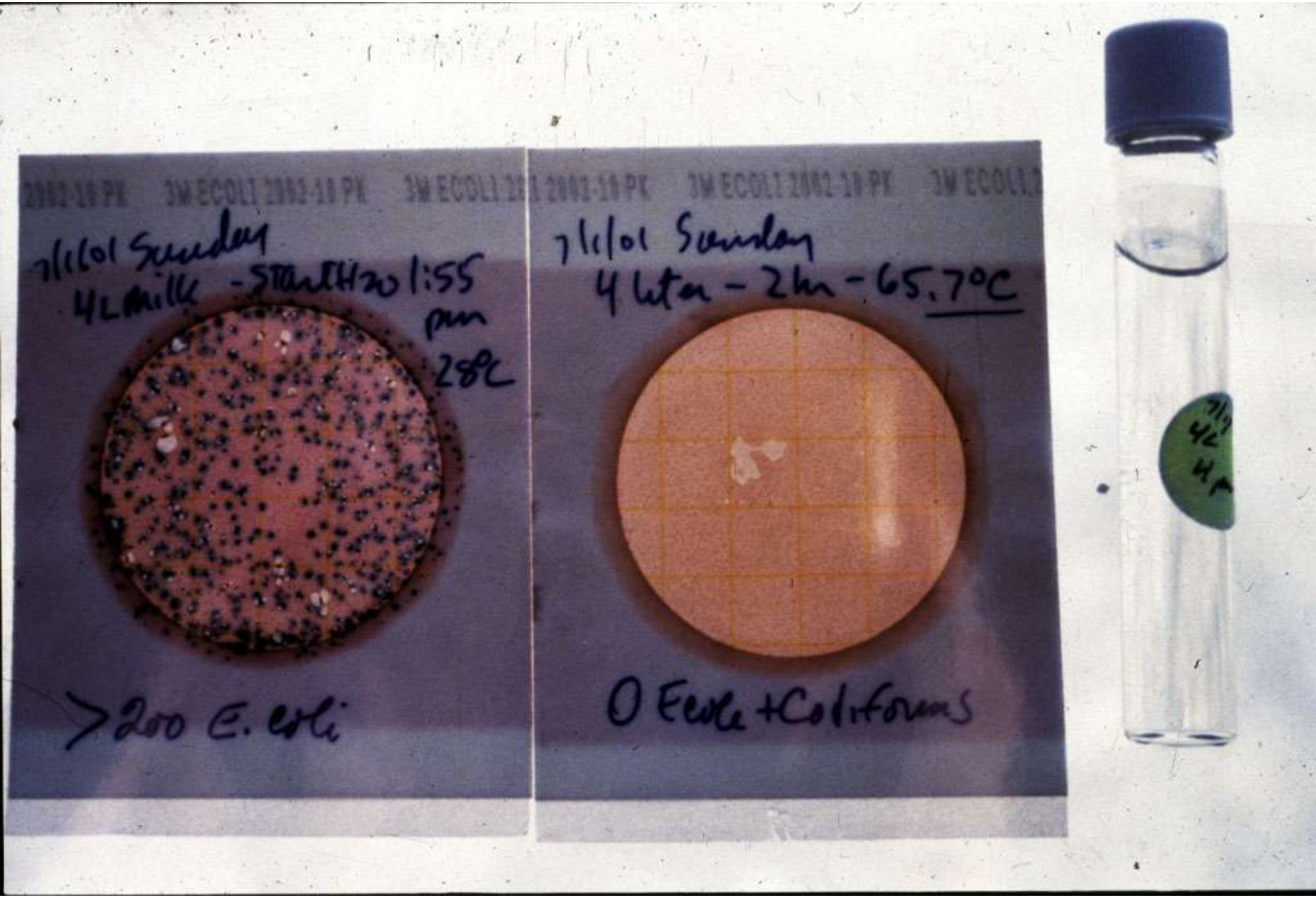
- RIT NGIMANI
- TET MALER
- CHUAK PI MODHO
- GENG' TUOCHE
- KUNG PESA

COOKER'S SHOP
HARAMBEE MARKET

OJECT OF SOLAR COOKERS INTERNATIONAL AND NYAKACH COMMUNITY


THE COOKERS SHOP
TEDO GI CHIENG
KONGOU MARKET


KIMBO
KIMBO


7/1/01 Sunday
4L Milk - Start H20 1:55 pm
28C
>200 E. coli
7/1/01 Sunday
4 hrs - 2hr - 65.7°C
0 Ecoli + Coliforms


476
475
Q-209
Combining Point Source Water Testing with Solar Water Pasteurization in Kenya
Robert H. Metcalf & Christine Polinelli
Department of Biological Sciences, California State University, Sacramento
Abstract
Introduction
Comparing Fecal Coliform MPN Tests with E. coli Tests
Methods and Results
Conclusions


SOLAR COOKERS INTERNATIONAL
(EAST AFRICA)
GITHUNGURI ROAD, KILELESHWA
P.O. BOX 51190-00200, NAIROBI, KENYA
PHONE 4347144, 4347295
FAX 4347144,
Email: sci@iconnect.co.ke
50M


SCI


SOLAR COOK
SCI