

Monitoring microbiological cleanliness of surfaces

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Automatic detection of cleanliness

Automatic

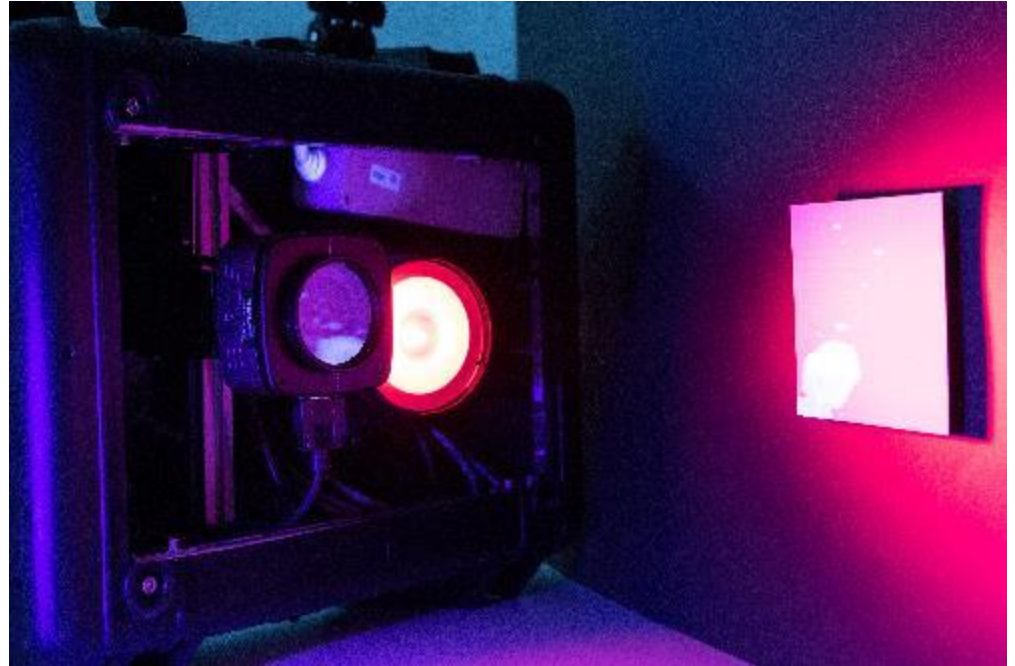
- Software
- Internet of Things

Detection

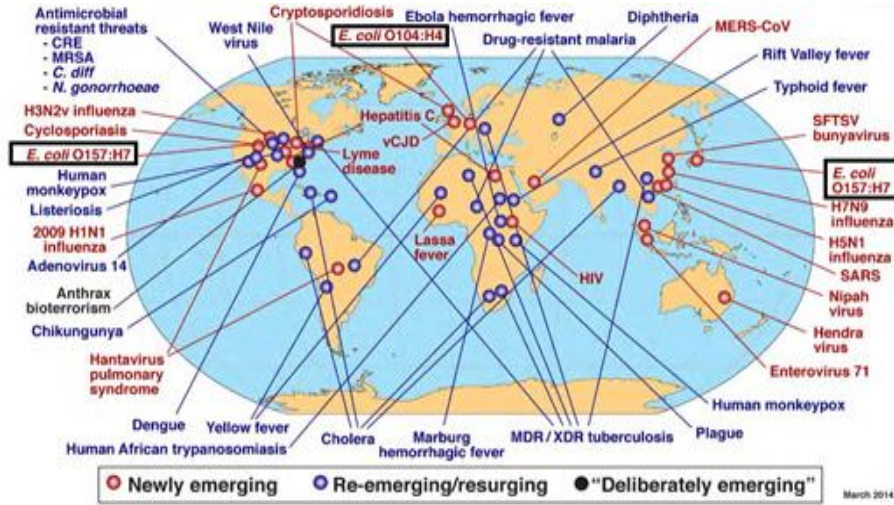
- Sensors
- Illumination

Cleanliness

- Microbiology
- Material characterization



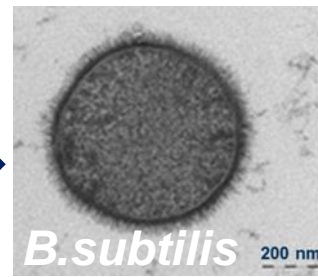
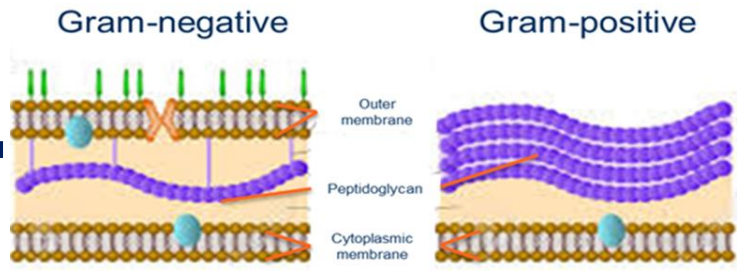
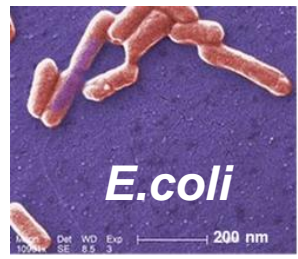
Global Examples of Emerging Infection Diseases



- Harmless and normally live in the intestines of healthy
- **Pathogenic strains** cause relatively brief diarrhea, abdominal cramps and vomiting



2013 → 2015



Modified from Morens et al. 2004 *Nature* 430:242

Currently 2 weeks from infection to diagnosis

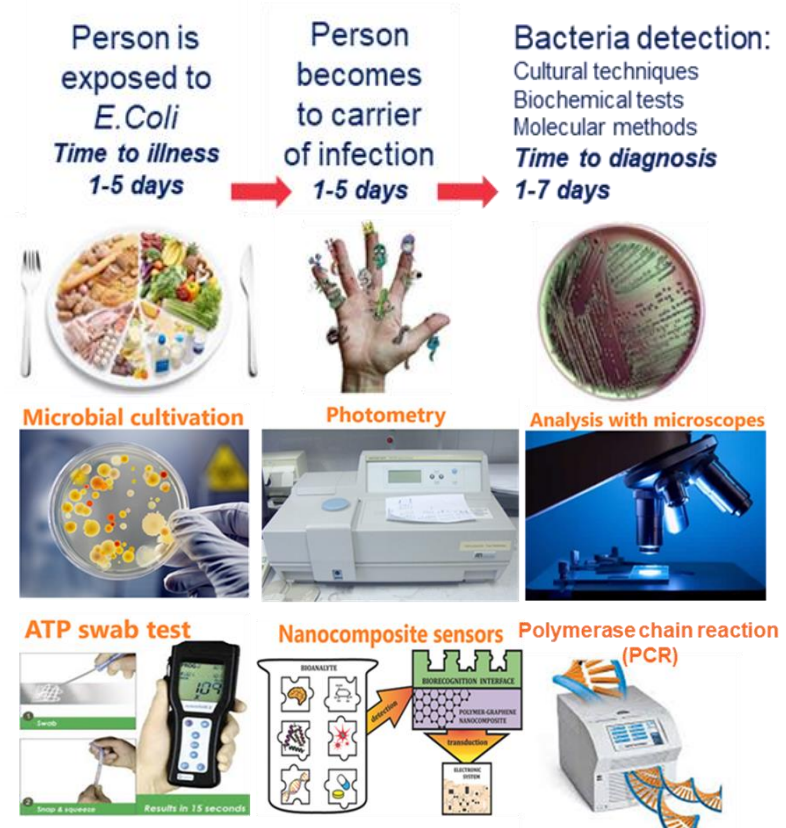
How we can prevent spreading of bacteria on touch surfaces in airports, ships, trains, hospitals, etc?

What we have?

- Sampling & sample preparation
 - Chemicals
 - Trained personnel
 - Expensive equipment/laboratory
- Detection time
 - from 1 hours to several days

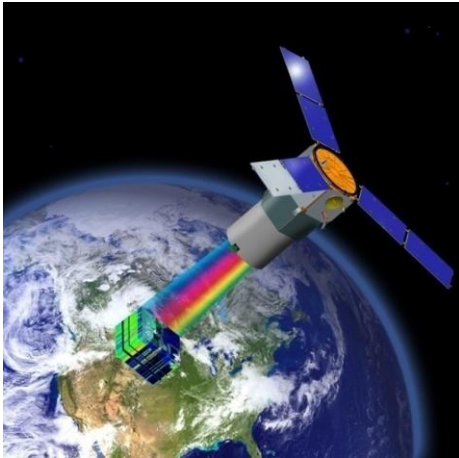
What we need?

- Easy
- Real-Time
- Rapid

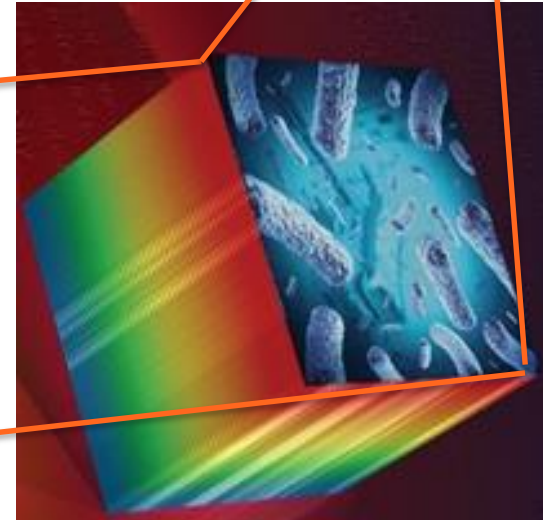


Earth surface is possible, Why not are touch surfaces?

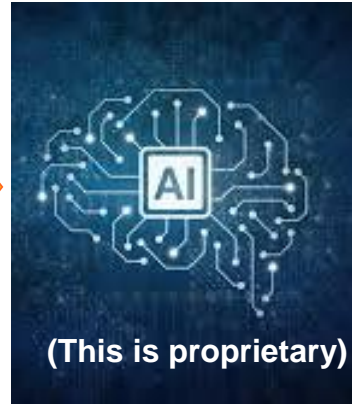
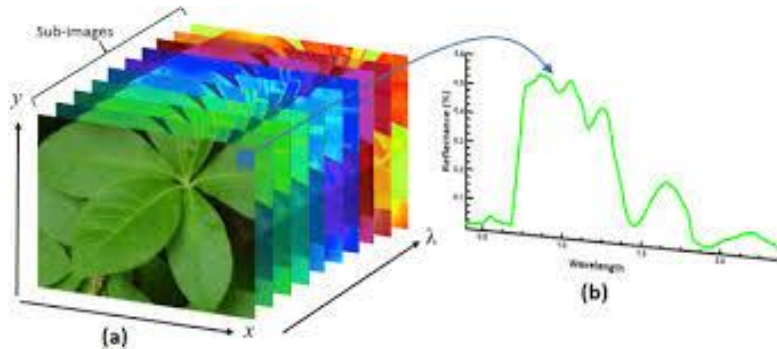
Crop diseases can be
detected from space



Could we detect
Microbial contaminants by
the same method
?



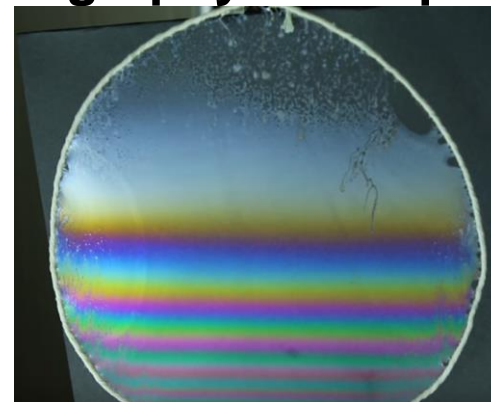
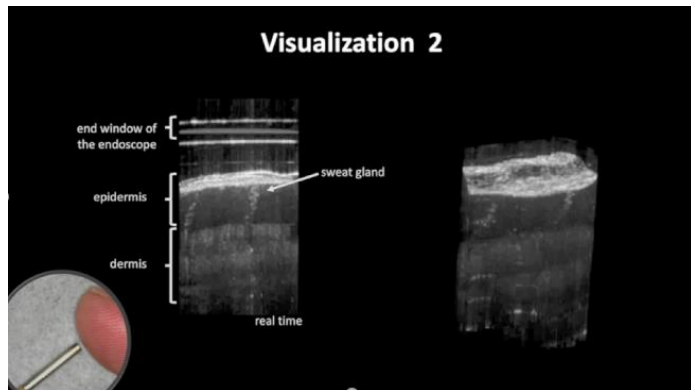
It works because light interacts differently between different objects



This is a leaf.

<https://doi.org/10.1016/j.biosystemseng.2017.09.009>

Compare with optical coherence tomography or soap film



<http://prism.osapublishing.org/Staff/Details/332604>

Simple proof-of-concept: oils on steel

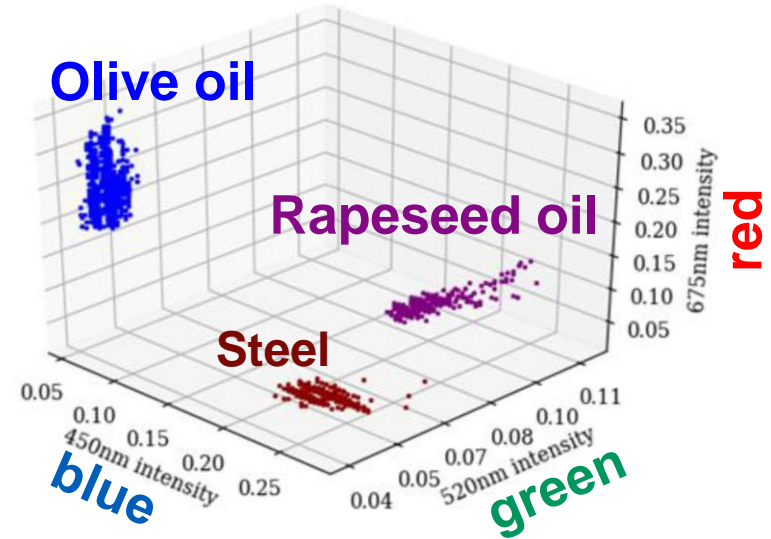
Separation of oils from metal

Uses fluorescence

- Input: UVA (black light, disco light)
- Output: red, green and blue

Off-the-shelf technology

- *Sita Process Solutions Ltd*
- Detection of storage oil residues



Realtime classification



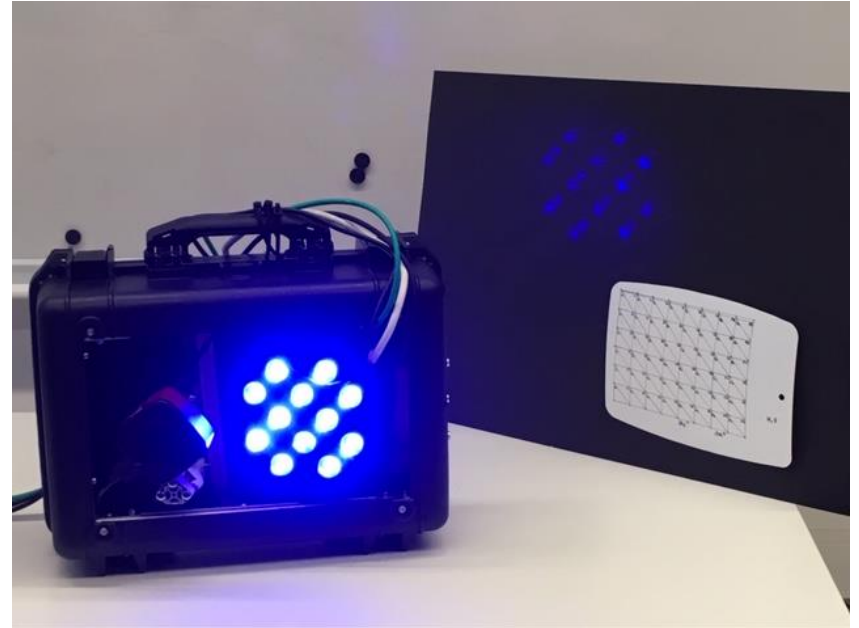
Video also at:
http://youtu.be/Op_mQyjUuTIs



Materials & Method

- Matrix - The solvent where bacteria is grown is Gibco LB Broth liquid
- Concentration of bacteria were from 0 to $6,5 \times 10^7$ cells/50 μL
- Metal & plastic plates surfaces
- 3 illumination (red, green, blue) & 16 imaging wavelengths were used

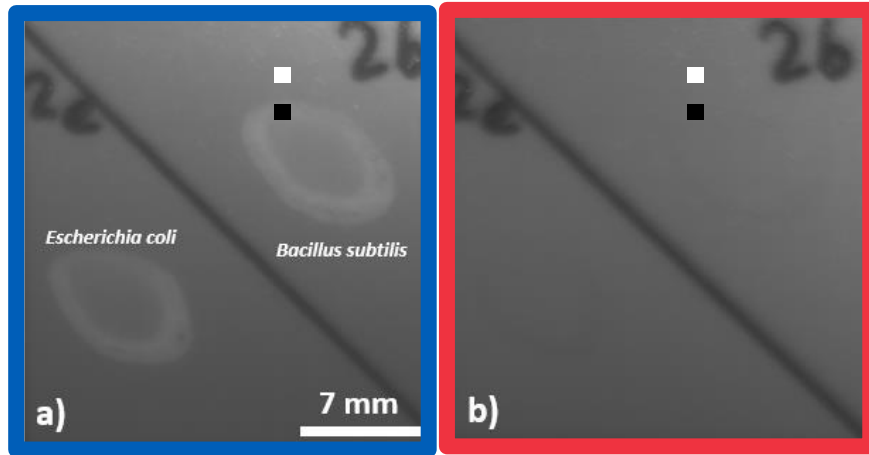
$$I_{\text{bacteria}} = I_{\text{bacteria spot}} - (I_{\text{background}} + I_{\text{matrix}})$$



Actual measurements with bacteria

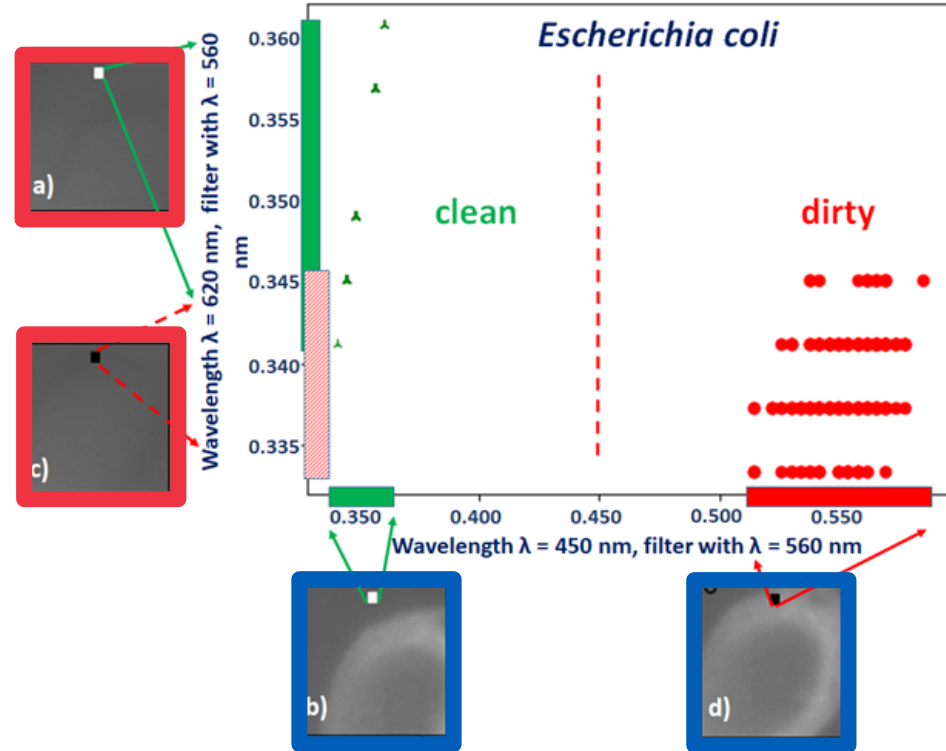
Now you see it, now you don't

- Same gray
- bacteria either visible or hidden
- Depends on wavelengths



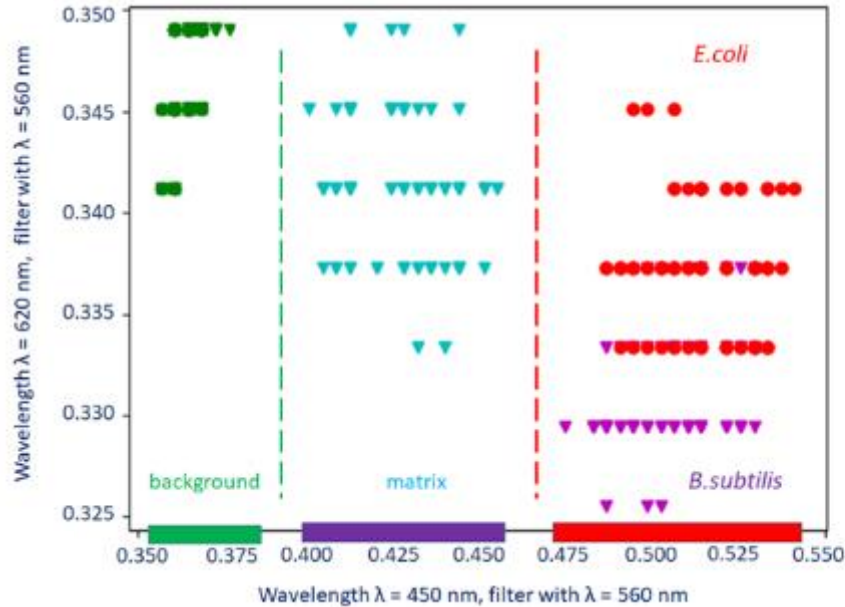
Blue light

Red light

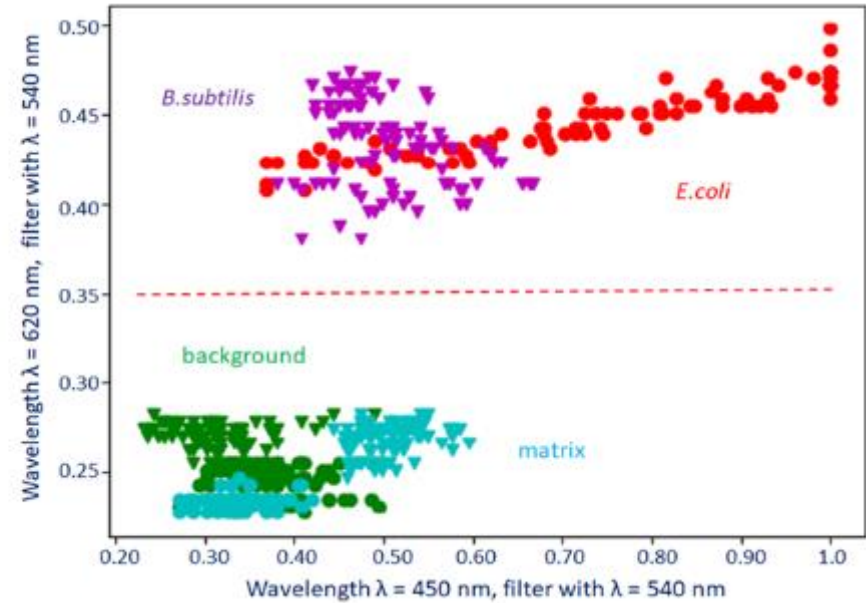


Bacteria identification

Plastic plate



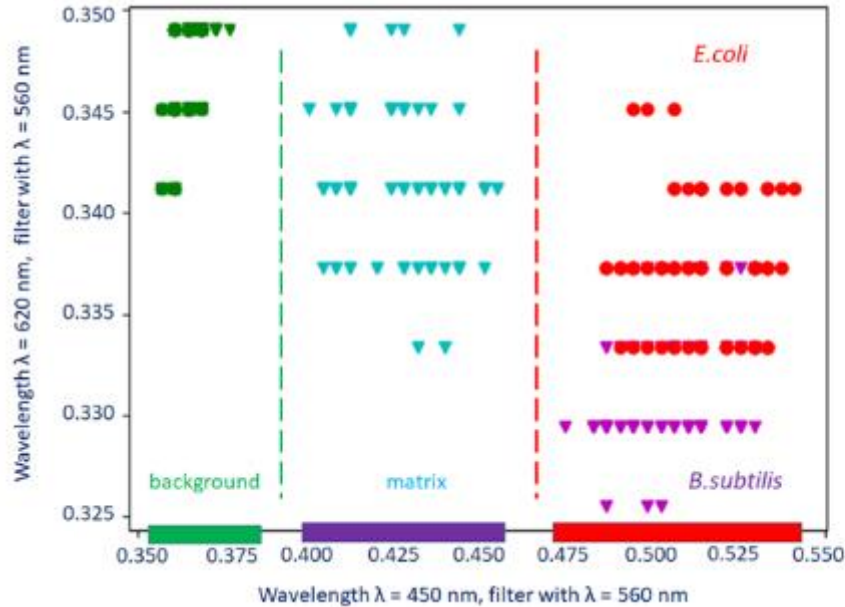
Metal plate



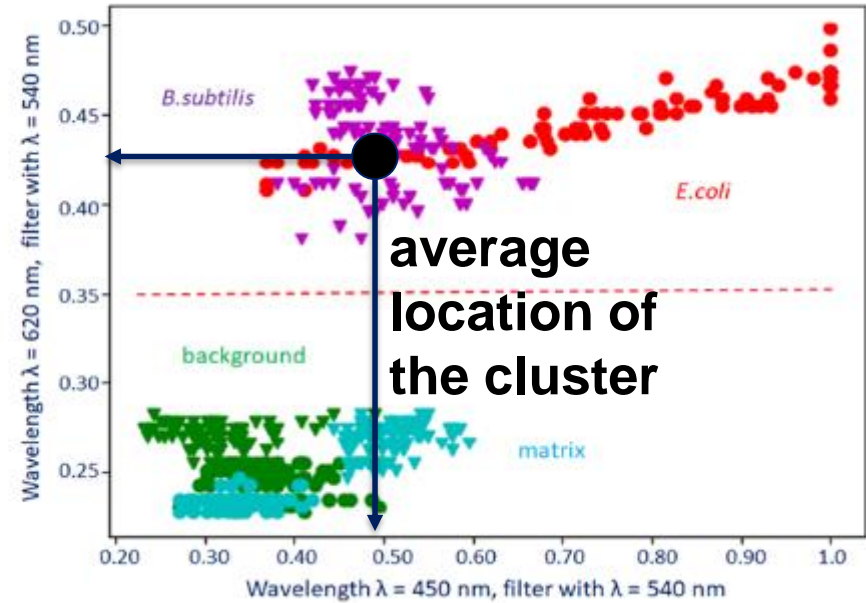
Separation of signals of background & matrix from bacteria
Separation of signals from *E.coli* & *B.Subtilis*

Bacteria identification

Plastic plate

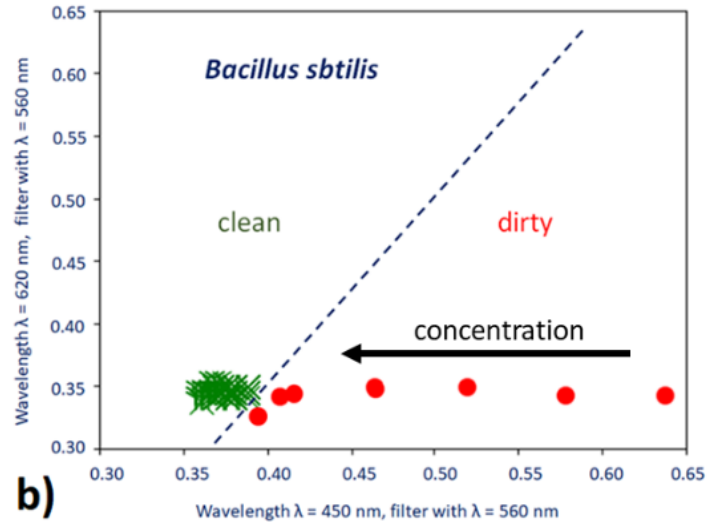
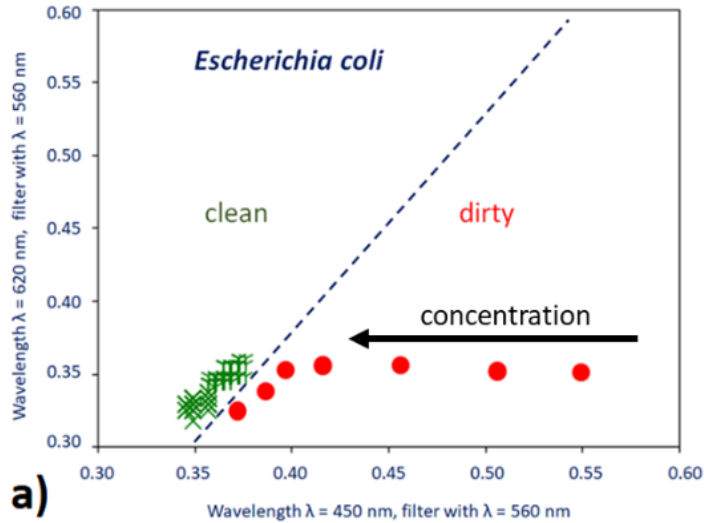


Metal plate



Separation of signals of background & matrix from bacteria
Separation of signals from *E.coli* & *B.Subtilis*

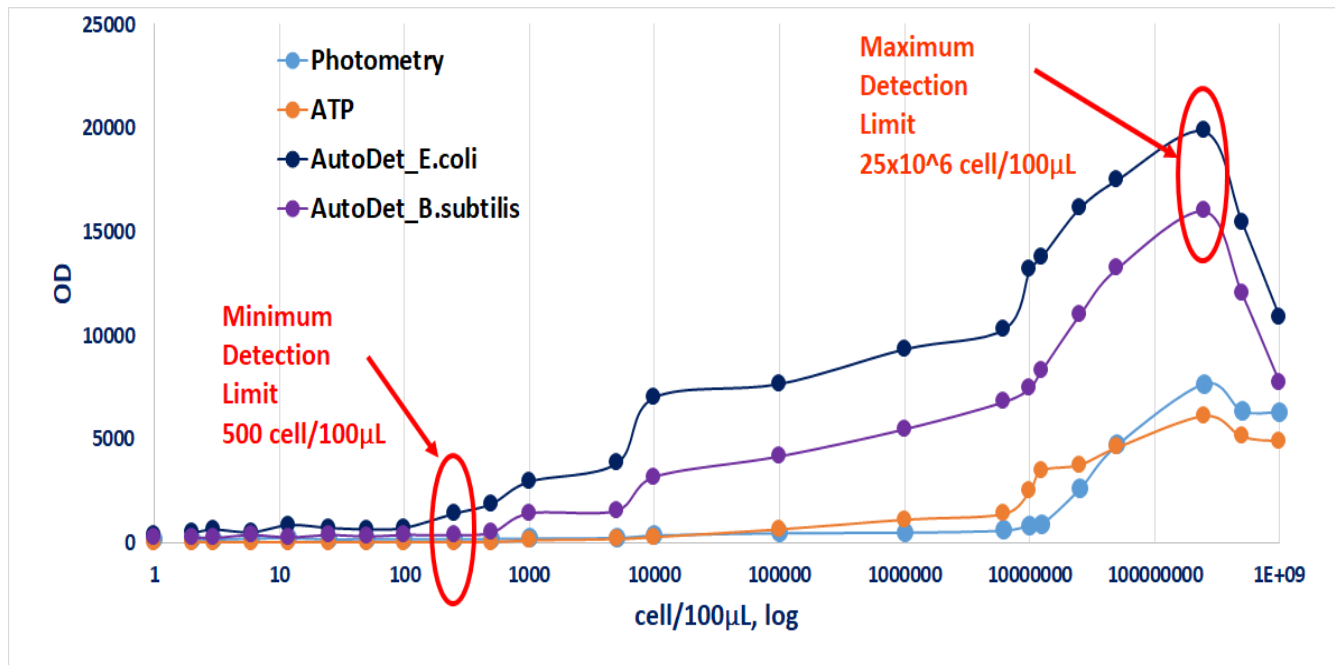
Decreasing concentration



Average location of the cluster 10^4 to 10^7 cells/50 μ L

Adenosine Triphosphate testing (ATP) & Photometry for developed method validation

- Lower Limit of Detection is 10-20 times less
- The Relative Standard Deviation is $\pm 3\%$
- The $OD_{AutoDet}$ is higher than for validation methods and 2 times more intense for 250 filter than for 324 nm



Real life example: hospital waiting room

Take images of various surfaces and classify regions of images to dirty and clean

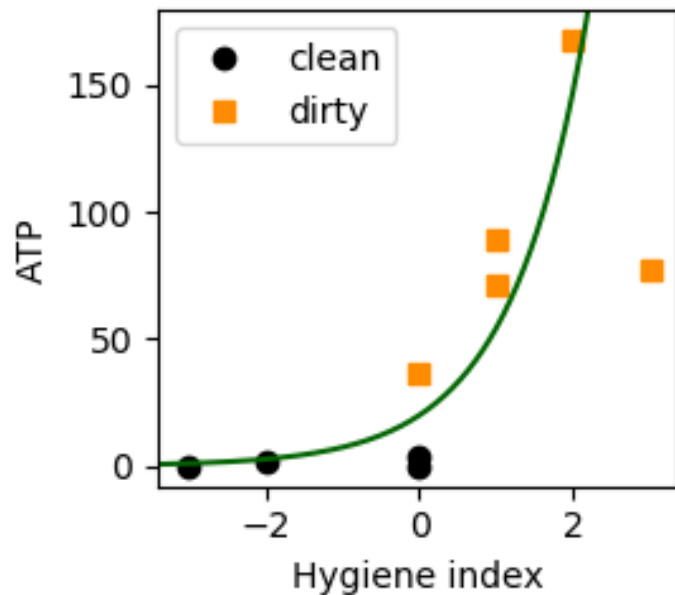
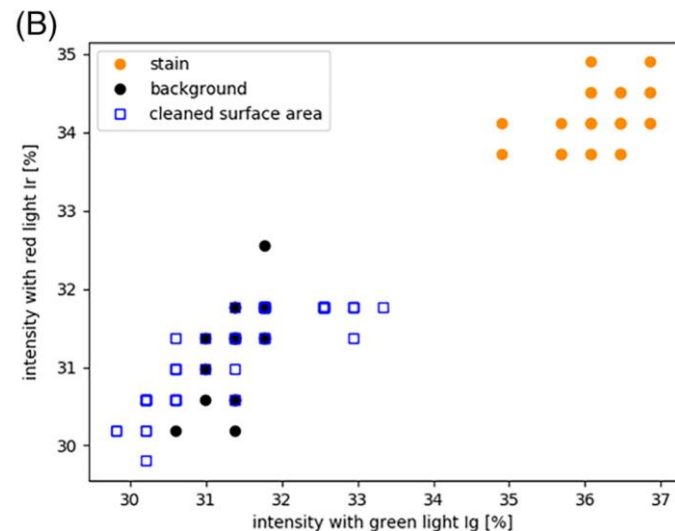
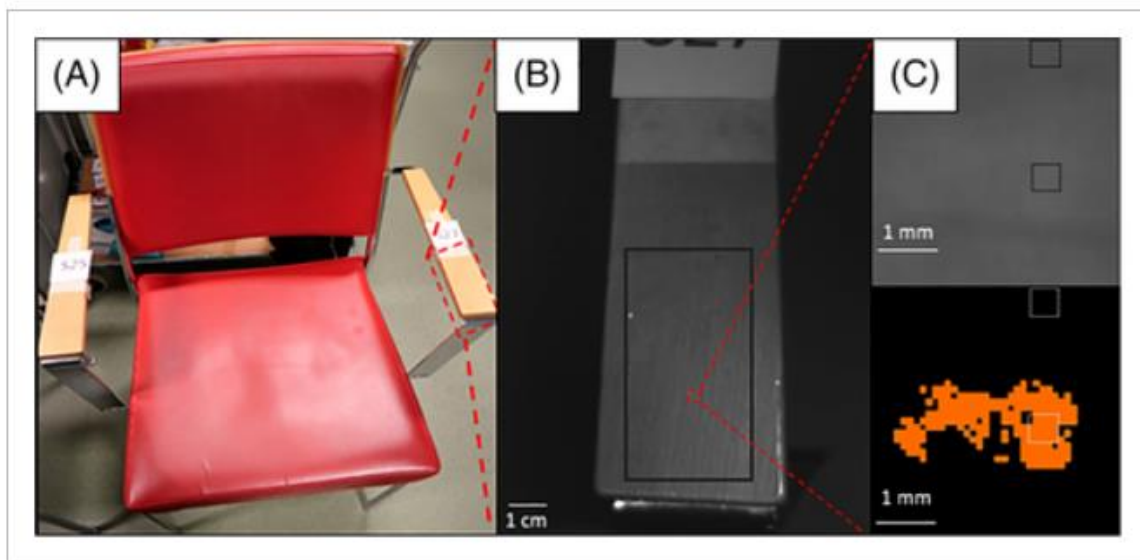


Hospital waiting room

Real data, real environment

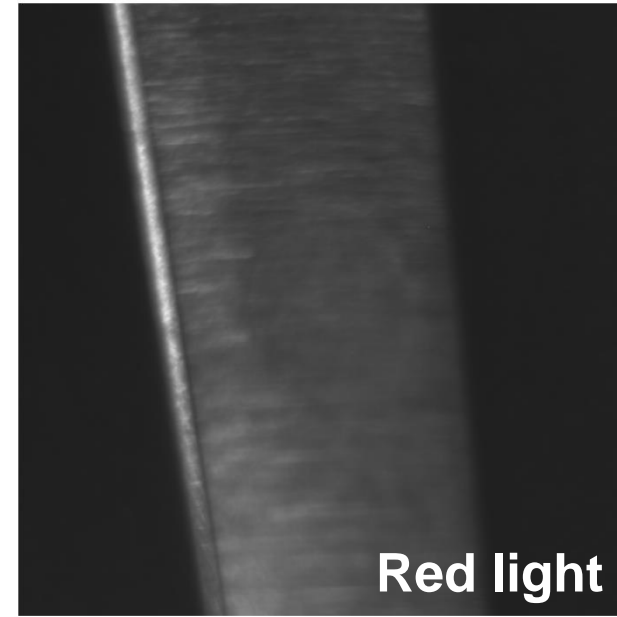
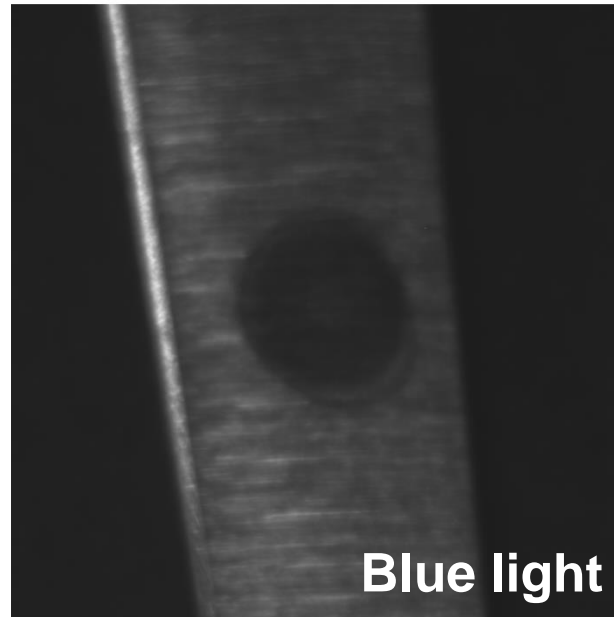
Visualize locations

Reduce all physics to “hygiene index”



Clear surface – blood on steel

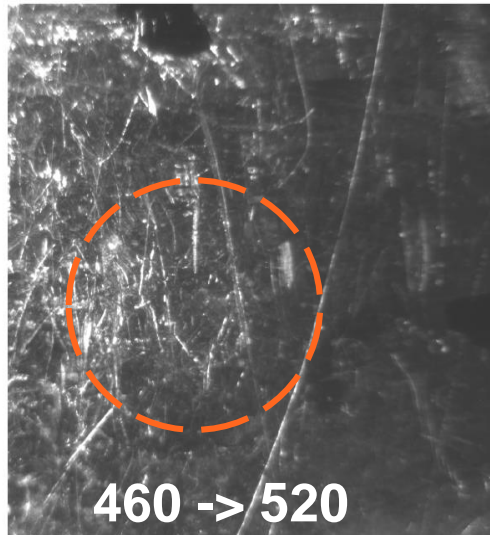
- Stain is clearly visible to human eyes
- *Now you see it, now you don't* – principle can be reproduced
- Automation is possible



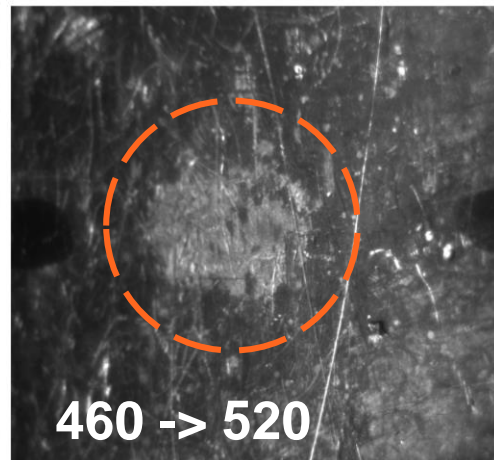
Oxidized surface

- *Stain is very hard to see with human eyes*
- *Now you see it, now you don't* – principle can be reproduced
- Automation is possible

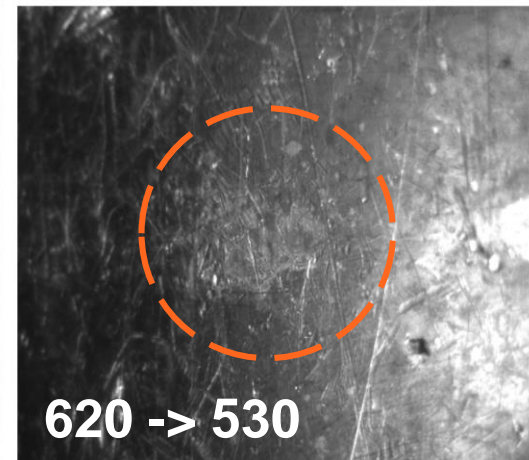
Backscatter



Reflection



Reflection



Remote detection contaminants possible

- More sensitive than ATP swab
 - Skip the sample preparation
 - Eliminate the usage of chemicals
 - Detection in minutes
 - Automated with infinitely long memory
-
- Now: detect biofilms
 - Next: identify bacteria, then viruses

