Developing a Condensation-Based Biosensor for Non-Invasive, Open Air Cancer Monitoring

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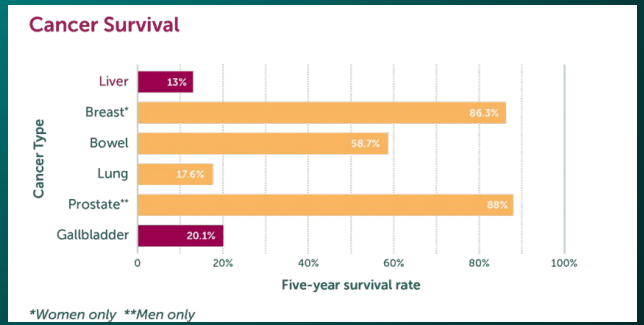
Introduction

Current cancer detection methods—including biopsies, imaging, and fluid tests—are often invasive, costly, and inaccessible. The American Cancer Society projects over 2 million new cancer cases and 618,000 deaths in the United States in 2025. Lung cancer remains the leading cause of cancer death (~226,000 new cases; 124,000 deaths annually), while liver cancer accounts for more than 42,000 diagnoses and 30,000 deaths per year. These statistics highlight the urgent need for earlier, safer, and more accessible diagnostics. Breath-based detection offers a promising non-invasive alternative, especially for patients with limited access to medical care. To address current sensitivity limitations, I developed the Airborne Biomarker Localization Engine (ABLE), which condenses water vapor on a cooled surface to enable liquid-based biomarker analysis. This study asks: Can an improved ABLE device collect greater condensate volumes over longer periods while capturing both volatile and non-volatile organic compounds?

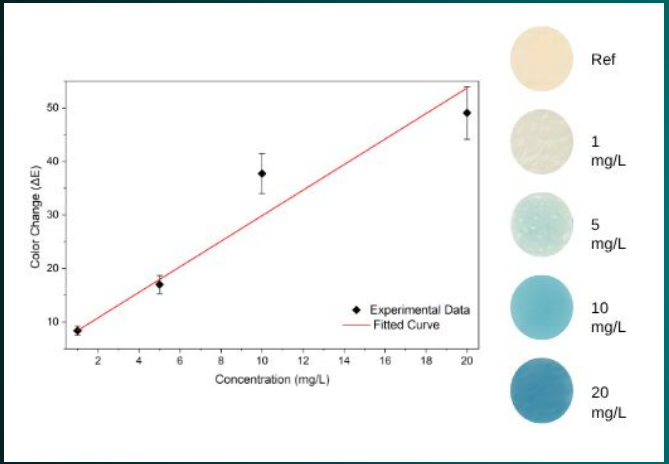


Procedure

1. Practice 3D modeling on SolidEdge
2. Model pieces for other versions of ABLE
3. Design a new segmented version of ABLE for longer collections
4. Model the segments of the new ABLE on SolidEdge
5. Print the segments on a PLA printer
6. Make adjustments to the segments so they would all fit
7. Analyze evaporation times of different biomarkers with an optical contact angle microscope
8. Test new ABLE with controlled concentrations of glucose & water vapor for 10 minutes
9. Measure amount of sample collected
10. Calculate color change on a glucose test strip using the L.a.b. formula (E=L2+a2+b2)where E is the color, L is lightness, a is red/green, and b is yellow/blue
11. Repeat tests and analysis with concentrations of ethanol

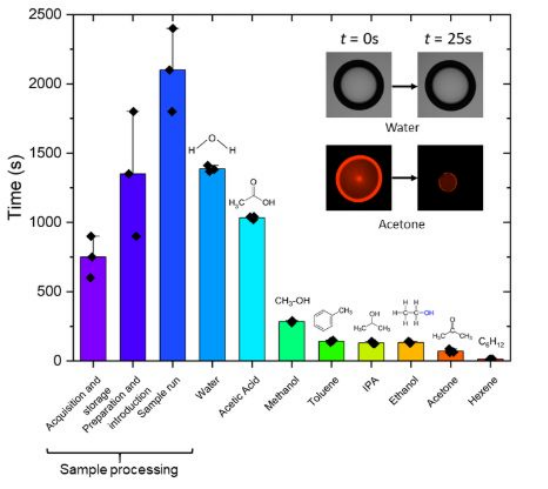
Data

Color Change Graph for Different Concentrations of Ethanol



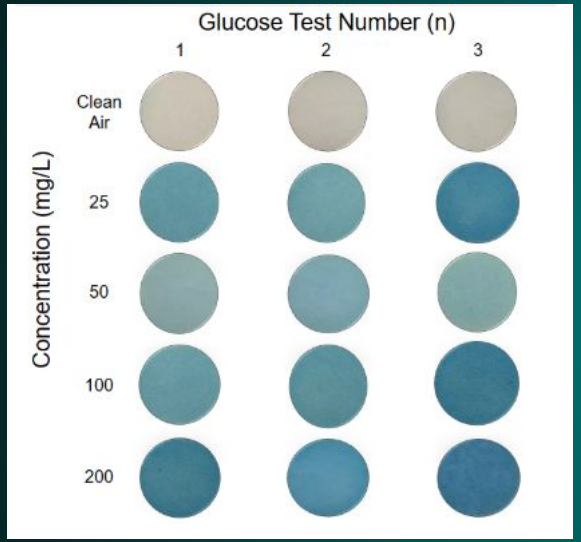
The above figure shows the color change on the ethanol test strips from samples collected with the new ABLE device. Created by Yamin Mansur with OriginLab.

Evaporation Times of Different Compounds



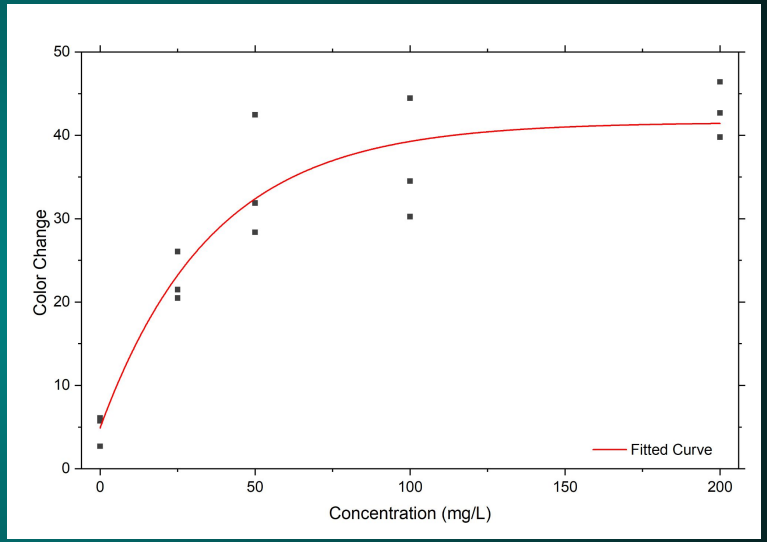
The above graph shows the average evaporation time for different biomarkers based on three (3) trials. An optical contact angle microscope was used. Created by Amio Ritwik with OriginLab.

Data



The above figure shows the color change on the glucose test strips from samples collected with the new ABLE device. Created by Yamin Mansur with OriginLab.

Color Change Curve for Different Concentrations of Glucose



The above figure was made based on color change calculated from three (3) collections at each of the different concentrations of glucose. Created by Amio Ritwik with OriginLab.

Data Analysis

Glucose ANOVA Test

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	4	2692.1077	673.0269	25.8102	0.00002985
Error (within groups)	10	260.7604	26.076		
Total	14	2952.8681	210.9192		

The table above shows the results of an ANOVA test done on the glucose color change. Made by Ethan Abbott with a ANOVA calculator.

Result

Glucose solutions were tested to validate device performance. Increasing glucose concentrations produced progressively greater color changes, as shown in the “Glucose Test Strip Comparison” and “Glucose Color Change Curve” graphs. ANOVA analysis of the color change values yielded a p-value near zero, confirming a statistically significant difference between glucose concentrations. Ethanol testing showed a similar concentration-dependent trend, though the number of trials was insufficient for ANOVA analysis. Together, these results demonstrate that this version of ABLE can successfully collect both volatile and non-volatile organic compounds.However, the “Biomarker Evaporation Times” graph highlights a key challenge in airborne biomarker analysis: rapid evaporation. Effective analysis of condensed biomarkers from exhaled breath will require near-immediate processing after condensation to preserve sample integrity.

Conclusion

The ABLE device demonstrates strong potential as a non-invasive platform for early cancer detection, reducing reliance on invasive procedures and frequent clinical visits. By enabling breath-based biomarker collection, ABLE could significantly expand access to disease monitoring, particularly in low-resource or underserved settings. This redesigned model performs comparably to the original device while improving collection duration, enhancing overall practicality. Next steps include continued validation using glucose solutions to ensure consistent and reproducible condensate collection, followed by extended-duration trials to further evaluate efficiency and performance. Integrating a low-cost, real-time condensate analysis sensor will be critical to advancing functionality while maintaining affordability. With continued refinement and validation, ABLE has the potential to transform early disease detection by making non-invasive, accessible diagnostics a realistic option for widespread public health application.