

# A Microfluidic Device for Detection of Water Contamination from Hydraulic Fracturing

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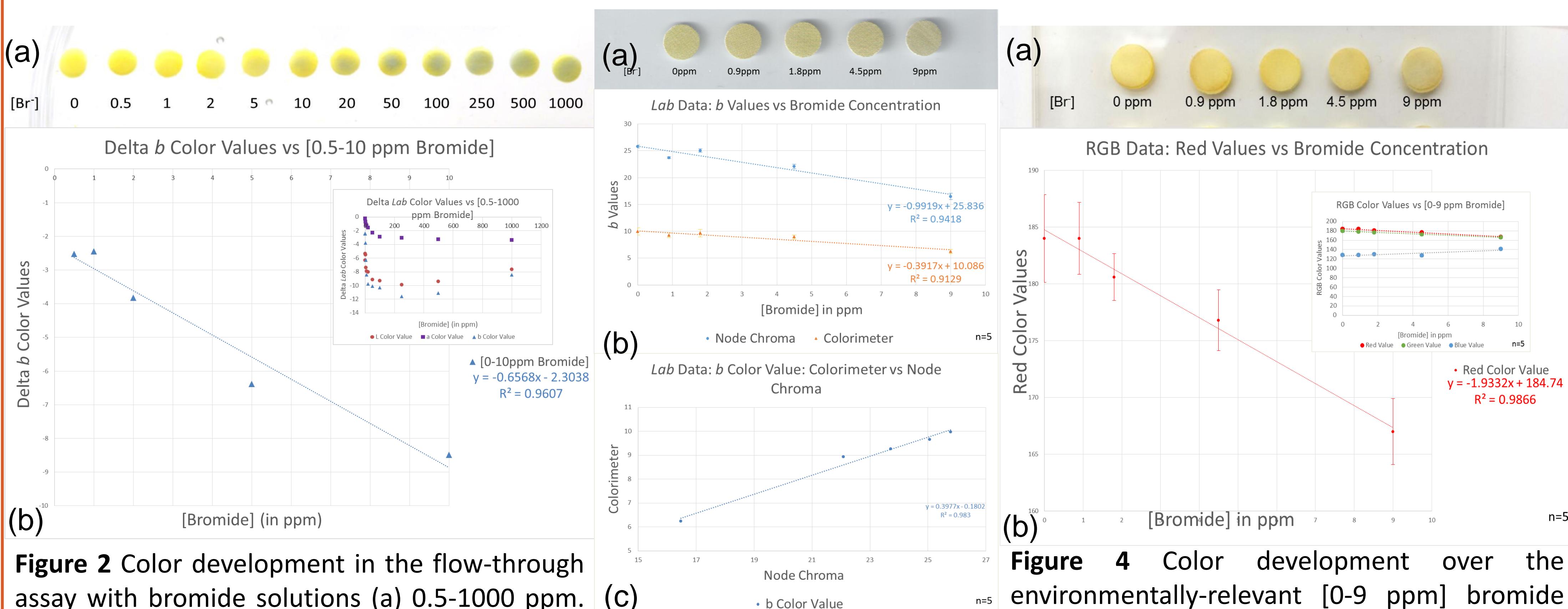
Hydraulic fracturing (fracking) has made shale gas accessible and economical. Despite efforts to reuse the wastewater produced, large quantities of wastewater still remain. The long-term environmental risks of wastewater leaking into water sources for human use have yet to be evaluated. Current water analysis methods are not designed for evaluation of water source contamination from fracking processes. As these valuable resources are utilized, new approaches are needed to assess and maintain environmental compliance and safety. We report on the design and development of a bromide detection method that can serve as an early indication of fracking wastewater leaks into source waters<sup>[1]</sup>. An established chemistry<sup>[2]</sup> was used to design a new flow-through device for the colorimetric detection of bromide in water.

The chemistry for this reaction is utilized in a triple layer flow-through design. By separately depositing and drying the buffer, indicator and oxidant, a color change occurs after the application of a bromide solution.



**Figure 1** Assay preparation scheme (a). Each reagent is deposited onto a separate layer of Whatman #1 filter paper, then dried inside a vacuum oven at 25°C for 30 minutes. To use the Node Chroma detector (b) for assay analysis, a custom sample holder was designed (c) and built (d). The detector wirelessly connects to smartphones to obtain color measurements in both RGB and *Lab* color space (e).

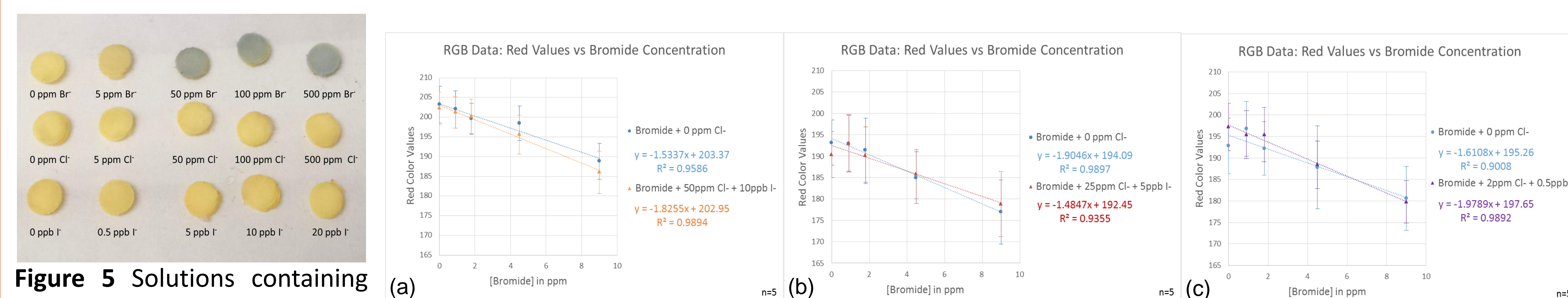
A yellow to blue-green color change occurs when bromide solutions are applied to the assay. *Lab* color space readings were obtained with a colorimeter. The colorimeter was compared to a Node Chroma color detector. Pairing the portable Node Chroma with a smartphone enables the user to obtain on-site RGB color readings.



**Figure 2** Color development in the flow-through assay with bromide solutions (a) 0.5-1000 ppm. *Lab* color values were obtained with a colorimeter and plotted against concentration (b). The inset (b) shows the *Lab* color values plotted against the 0.5-1000 ppm range. Concentrations  $\leq 10$  ppm produced a linear relationship. Delta *b* shows the best linearity and sensitivity over the 0.5-10 ppm range. **Figure 3** Color surrogates of environmentally-relevant concentrations of bromide (a) were used to compare colorimeter and Node Chroma readings(b). Both readings were plotted (c).

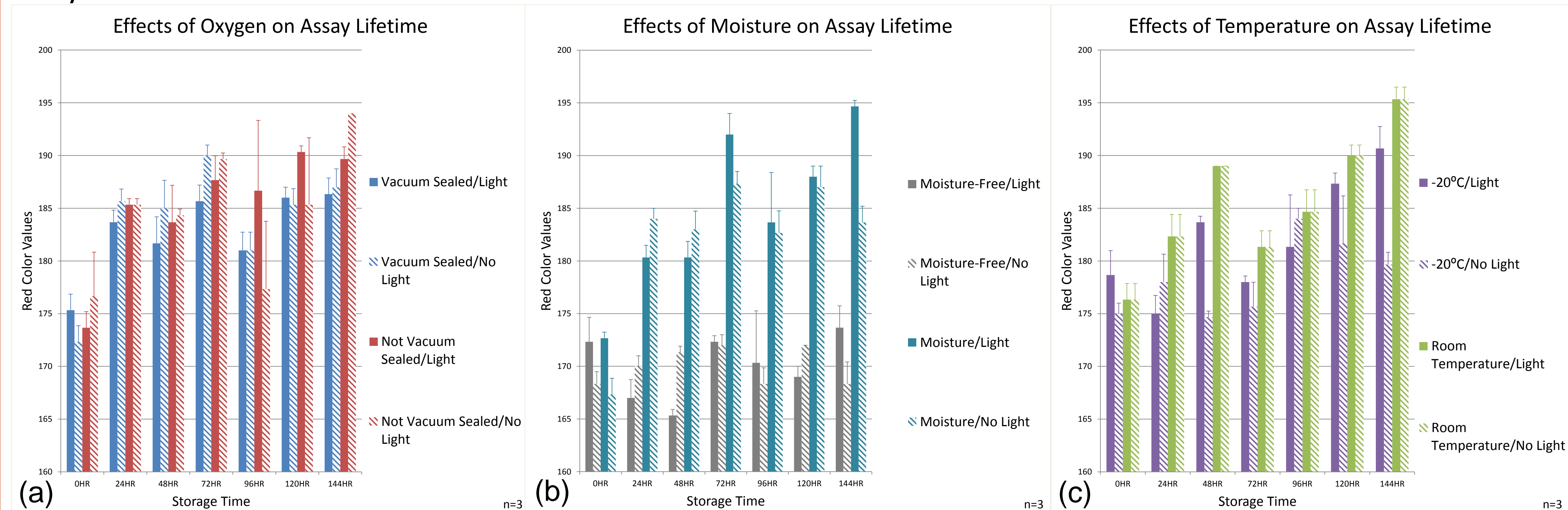
**Conclusion and Path Forward** The chemistry of this assay has been optimized for the relevant concentration range of bromide, and the data indicates that storing the assay under a moisture-free environment will extend the lifetime and reliability of the assay. In the presence of environmentally-high concentrations of chloride and iodide anions, some interference is observed. Future work will further characterize the robustness of the assay against such interference. In addition, this work presents a flow-through assay, but future work will include adapting the assay to a lateral-flow format. Lateral flow will further simplify the fabrication process of the assay, as well as simplify the final chip design. In conclusion, this project has laid the groundwork for developing a bromide detection device for analyzing water. This device has potential applications in portable, inexpensive water analysis for early detection of water source contamination from fracking operations.

The flow through assay was assessed for interference from chloride and iodide at environmentally-relevant concentrations<sup>[3, 4]</sup>.



**Figure 5** Solutions containing bromide, chloride and iodide were applied to the flow-through assay. Only the group treated with bromide developed the color change. **Figure 6** Bromide solutions were spiked with a range of environmentally-relevant concentrations of iodide and chloride anions and compared to solutions that contained only bromide anions. High concentrations of these anions (a) showed signs of interference. Mid-range (b) and lower (c) concentrations of iodide and chloride showed less interference.

To test the effects of environmental storage conditions (light, oxygen, moisture and temperature), assays were stored under various conditions. Over a period of 7 days, a 10 ppm bromide solution was applied to each assay and R values were obtained with the Node Chroma. R values of assays with a storage time  $\geq 24$  hours were compared to the R values obtained from assays with storage times of 0 hours. Increasing R values indicates a decrease in assay activity and color intensity. The experiments suggest a moisture-free storage environment is crucial to the stability of the assay.



**Figure 7** The effects of four environmental conditions (light, oxygen, moisture and temperature) were evaluated to determine the storage requirements for the assay. To create an oxygen-free environment, assays were vacuum sealed and stored under vacuum (a). To create a moisture-free environment, assays were stored with desiccant and sealed (b). To determine the effects of temperature on assay lifetime, assays were stored at -20°C. To determine the effects of light, the assays were stored under dark conditions. The R values were obtained daily to evaluate assay stability.

## References

- [1] Rahm, B. G.; Riha, S. J. *Environ. Sci. Process. Impacts* 2014, 16, 1400.
- [2] Lepore, B. J.; Barak, P. *Soil Sci. Soc. Am. J.* **2009**, 73, 1130.
- [3] Mullaney, J. R.; Lorenz, D. L.; Arntson, A. *Chloride in groundwater and surface water in areas underlain by the glacial aquifer system, northern United States*; U.S. Geological Survey Scientific Investigations Report 2009–5086; U.S. Geological Survey: <http://pubs.usgs.gov/sir/2009/5086/>; p 41.
- [4] Neal, C.; Neal, M.; Wickham, H.; Hill, L.; Harman, S. *Hydrol Earth Syst Sci* **2007**, 11, 283.