INNOVATING CROSS-DOMAIN SOLUTIONS TO DETECT EMERGING BIOLOGICAL THREATS

Low Burden Sensors For In-field Detection Of Water Contaminants Based On Synthetic Biology And Cell-free Expression Systems

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The ability to detect harmful contaminants in water is critical for health and safety in both field-forward and resource-poor environments. Microorganisms have naturally devised mechanisms for sensing and responding to a variety of analytes in the environment, and this molecular machinery can be exploited and further engineered via synthetic biology to generate sensors against a multitude of threats. Despite the potential, deployment of these sensors remains a challenge. For cell-based sensors, these challenges include the nutrient requirements of living cells and concerns surrounding the possible release of genetically modified organisms. Sensors based on cell-free expression (CFE) systems, however, overcome many of the limitations of whole-cell sensors, enable detection of contaminants toxic to living systems, and hold great promise for providing rapid, in-field detection capabilities. CFE systems can be freeze-dried onto paper substrates, and following rehydration at the point of need, a measurable signal is produced in response to the target analyte. These paper-based sensors are low SWaP-C, disposable, simple to use, and multiplexible.

Here we describe a tri-service effort to develop CFE sensors to detect the toxic water contaminants arsenic, cadmium, and mercury. These sensors utilize engineered genetic circuits that express naturally responsive bacterial transcription factors and a visualizable reporter protein. Under laboratory conditions, all three sensors can detect heavy metals at or below Military Exposure Guideline (MEG) levels, and the arsenic and mercury sensors achieve detection limits below the World Health Organization (WHO) recommended levels within 30 minutes. The sensors were subsequently tested and optimized for field-relevant conditions enabling detection at target concentrations in spiked environmental water. Current efforts aim to further develop and manufacture these sensors and continue to push the technology into the field. A key feature of the underlying biotechnology presented here is its adaptability to other sensor and detection modalities enabling sensing of other chemical and biological threats, including pathogens, proteins, small molecules, and toxins. In the future, this approach could be expanded to detect a wider range of contaminants and allow for simultaneous in-field detection of multiple water hazards in a low SWaP-C package.

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