INNOVATING CROSS-DOMAIN SOLUTIONS TO DETECT EMERGING BIOLOGICAL THREATS

A Fieldable System for Automated Nucleic Acid Extraction

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The ability to detect biological threats in the field with sufficient sensitivity, specificity, and target coverage is crucial for protecting the warfighter against the ever-changing threat landscape. Current methods are limited in the number of agents that can be detected and typically require prior knowledge of potential threats. Sensitive and multiplexed detection of nucleic acid targets from biological samples is a challenging problem, which is typically addressed using specialized equipment in a laboratory setting. The process involves several key steps including sample collection, sample lysis, nucleic acid extraction, nucleic acid detection, and signal readout. Each of these steps is often achieved using separate pieces of equipment, specialized processing kits, or a sequence of manual steps which require user intervention. For these reasons, the existing process is not suitable for in-field use.

Draper is addressing this challenge by developing a low SWaP-C, automated, and fieldable nucleic acid extraction device for total nucleic acids extraction from bacterial and viral samples. The portable system accepts a disposable palm-sized microfluidic cartridge, which is preloaded with all reagents needed for nucleic acid extraction. The system accepts unprocessed biological samples, such as nasopharyngeal swabs, and provides extracted total nucleic acids with performance comparable to manual protocols. The cartridge comprises a microfluidic network, with passive (e.g., extraction column, check valves) and active (e.g., syringe pump, selector valve, heater) components. The active components and fluid handling within the cartridge are computer-controlled and operated in an automated fashion following a predefined series of processing steps. These steps were optimized to provide high nucleic acid yield from unprocessed samples. Following an 18-minute extraction process, the user collects the extracted nucleic acid within a removeable centrifuge tube. An integrated waste reservoir with absorptive material is contained underneath the cartridge for easy reagent disposal. Furthermore, the disposable cartridge is designed using materials that are amendable for low-cost and large-scale manufacturing.
We have demonstrated that nucleic acids extracted in our automated system are compatible with several standard downstream processing steps, including sequencing, (RT)-qPCR, Nanodrop, and Qubit. In particular, we focused our study around sequencing of bacterial samples using fieldable sequencers from Oxford Nanopore Technologies (ONT). Three concentration levels of a gram-negative bacteria were spiked into a complex sample of background nucleic acid prior to automated nucleic acid extraction. The device-extracted nucleic acid was then assessed using 16S sequencing and demonstrated successful identification of the bacteria at a similar read quality as manually-extracted samples.

Our fieldable nucleic acid extraction system performs the critical first step ahead of downstream detection for field forward assessment of biological threats. Our microfluidic cartridge provides an unprecedented capability in enabling high yield and purified nucleic acid extraction that is compatible for fieldable sequencing and other nucleic acid-based detection techniques. In this presentation, we will share recent progress and results from our development of the disposable microfluidic cartridge for automated nucleic acid extraction and successful sequencing results.