INNOVATING CROSS-DOMAIN SOLUTIONS TO DETECT EMERGING BIOLOGICAL THREATS

Biosurveillance In Arctic Permafrost Soils Reveals Emergence Of Pathogenic Bacteria And Viruses

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Arctic permafrost soils are a reservoir of microbial life, including viruses, bacteria, and fungi, which remain frozen but viable. As permafrost thaws, these microbes become more active and pose potential risks to ecosystem function, infrastructure stability, and human health. Consequences of permafrost include infrastructure subsidence, economic loss and impact on people's livelihoods, and disruptions to DoD training and operations across the Arctic and sub-Arctic. For instance, in 2016 a thaw event in Siberia resulted in the release of dormant anthrax spores from a long-frozen reindeer carcass, killing nearby grazing reindeer and threatening local human populations. As the frequency and extent of global climate disasters continue to increase, there will be greater need for biosurveillance across geographical domains and ecosystems to identify potential emerging pathogens. While global temperatures have increased by 1.2°C since the start of the industrial revolution, the Arctic has warmed by 3°C, with devastating impacts for people and ecosystems. To date, very little biological information exists about the potential health risks to humans from pathogens frozen in permafrost. Despite this, viable viruses and bacteria have been found in thawing permafrost, with some reports identifying zoonotic and human pathogens. To understand the potential emergence of pathogenic bacterial and viral communities in rapidly degrading permafrost soils we surveyed degraded permafrost at various geographical sites shotgun sequencing and analyzed our results using the Pathosystems Resource Integration Center (PATRIC) database and bioinformatics resource (Gillespie 2011). PATRIC is a genomics-centric relational database designed to integrate and annotate genomic data to allow for a comparative analysis of bacterial infectious agents with closely related free-living, symbiotic, and commensal species. Our analysis identified a wide variety of bacteria and viruses in our permafrost soils cores, including bacteriophage, zoonotic viruses, and bacteria. Our results revealed 35% of annotated metagenomic sequences were bacteria with some high abundant species known to carry human and plant pathogen traits such as Bradyrhizobium, Streptomyces, Polaromonas, and Pseudomonas. Viral pathogens were mainly zoonotic viruses and composed only 0.008% of annotated metagenomic sequences. The remaining 83% of metagenomic sequences were genes of unknown function, which highlights our limited ability to identify novel extant or extinct biological threats. If any of these genes of unknown function harbor mobile genetic elements such as plasmids and prophages (dormant viral genes) then rapid permafrost thaw could pose a risk of exposure human and animal populations to novel pathogens to which we may have no herd immunity. Thus, studying viral and bacterial emergence in varying spatial, temporal, and phylogenetic scales in permafrost soil ecosystems could provide a mode of surveillance for prevention of global biothreats. Our findings provide a foundation to leverage cross-domain solutions to establish biosurveillance programs for monitor emerging biological threats during abrupt climate changes at strategic sites. In addition, merging these data with climate models could provide predictive tools that will enable decision about locations, timing, and rates of emerging pathogen reservoir hotspots as well as classify biothreat levels.

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