

# Biosurveillance Of Emerging Viral Threats Through Indoor Air Sampling

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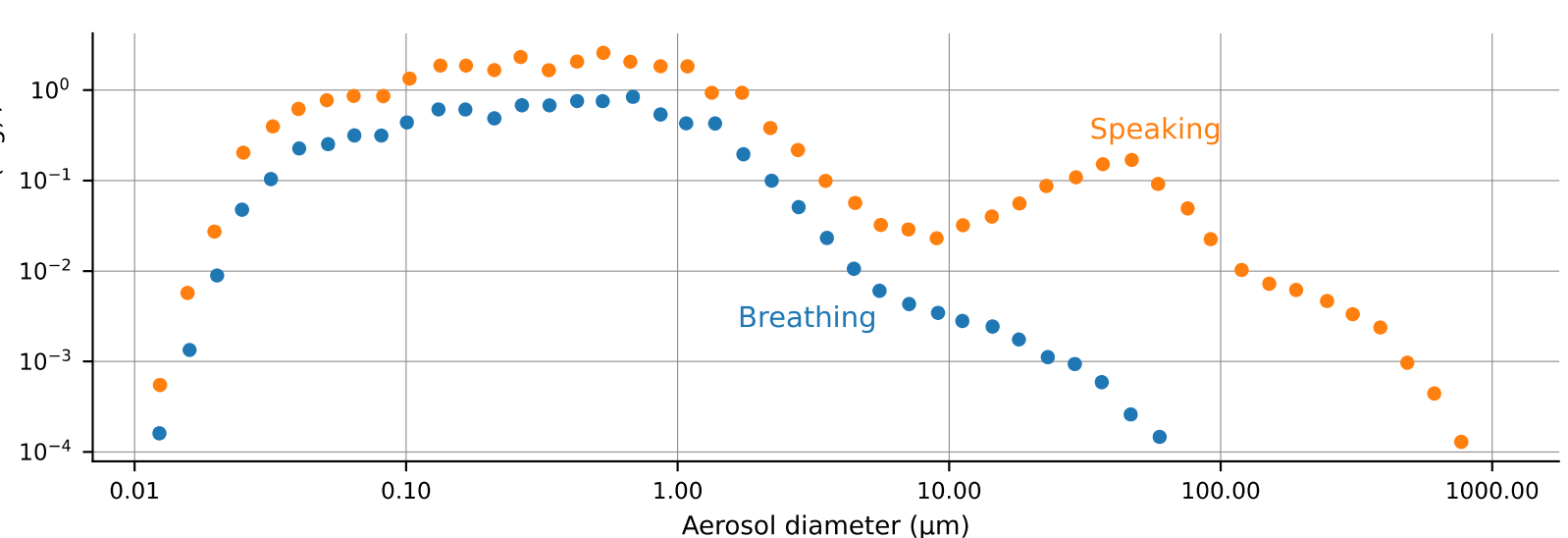
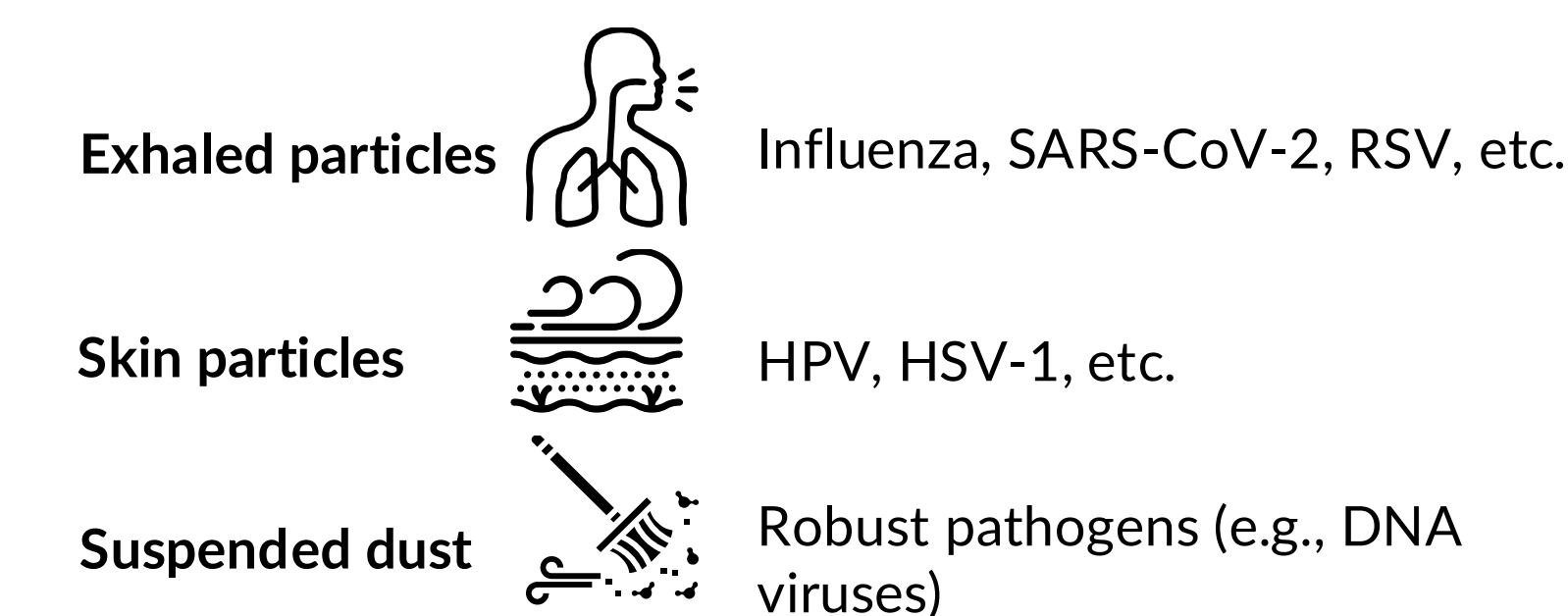
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**ABSTRACT:** Indoor air sampling presents a promising frontier for the early detection and surveillance of airborne viral threats. This review explores the potential of indoor air sampling for viral bioaerosol detection. We examine the viral content of indoor air, including sources, concentrations, and metagenomic profiles; compare various air sampling technologies; and assess strategic implementation in high-traffic locations. Our findings reveal that while viruses typically comprise less than 1% of metagenomic sequences in air samples, a diverse array of human-infecting viruses, including both respiratory and skin-associated pathogens, can be detected. We highlight the potential of HVAC systems and high-traffic areas like airports and hospitals as aggregators of viral bioaerosols from large populations. This research provides crucial insights for developing next-generation viral sampling techniques and biosurveillance networks, offering a foundation for enhanced biodefense capabilities and rapid response to emerging threats.

## INTRODUCTION

- Early detection of emerging viral threats is critical for national security and public health.
- Air sampling is particularly promising for biosurveillance because airborne transmission is a hallmark of many high-risk pathogens.
- Multiple U.S. government agencies, including DARPA, DHS, USPS, and ARPA-H, have invested in air sampling programs to detect biological threats.
- Our review explores indoor air sampling for viral bioaerosol detection, aiming to inform the development of robust, real-time biosurveillance networks that can detect both known and emerging viral threats, ultimately strengthening our national biodefense posture and rapid response capabilities.

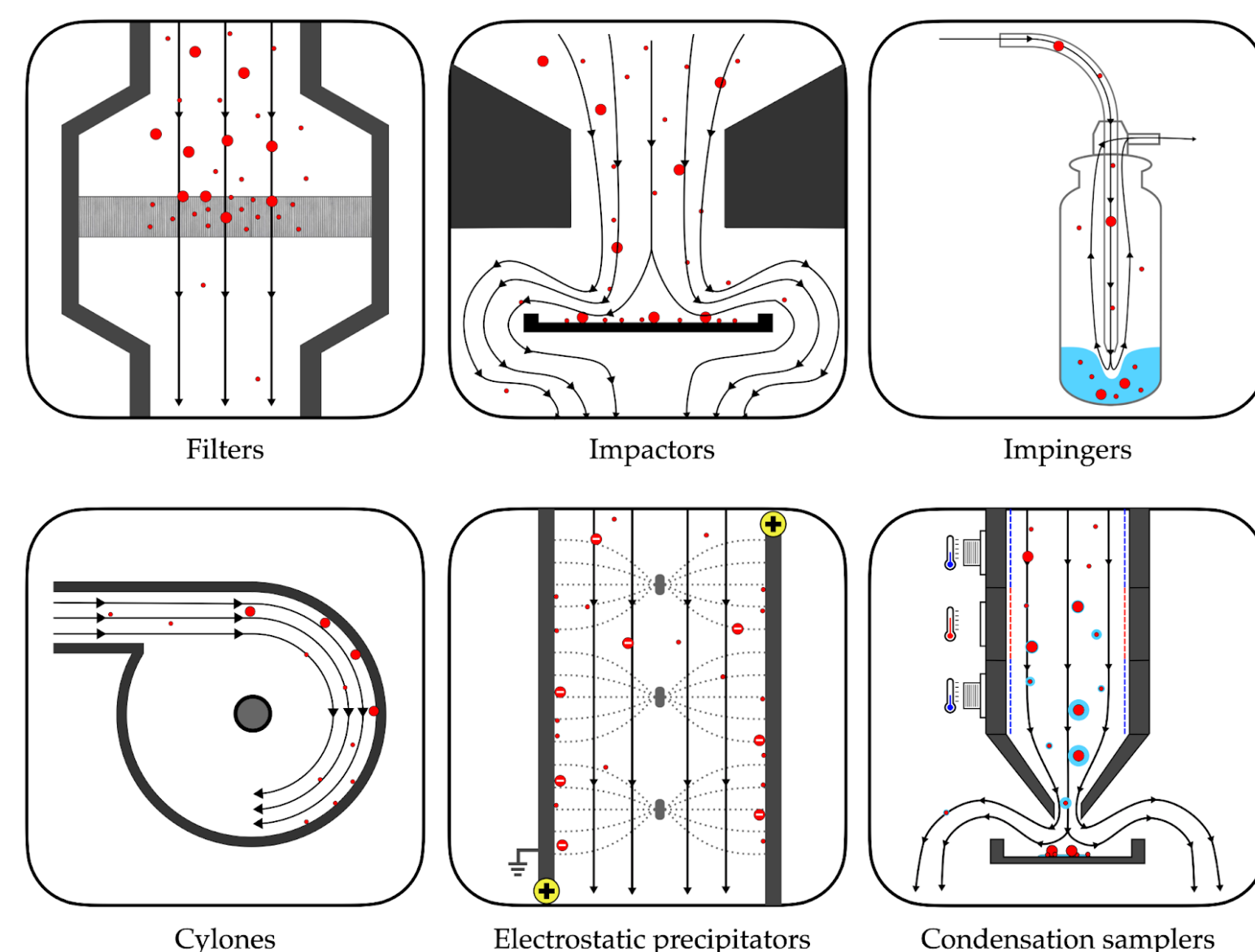
## SOURCES OF VIRAL NUCLEIC ACID



**Figure 1:** Experimentally-determined size distribution of respiratory aerosols emitted by healthy volunteers (Bagheri et al., 2023). Y-axis represents the log-normalized concentration of respiratory particles, as a function of the particle diameter (arithmetic mean across all test subjects)

## AIR SAMPLING METHODS

- Active**
- Employs powered air mover.
  - Provides snapshot of airborne microbial contents in the sampler's vicinity.
- Passive**
- Collects airborne particles after gravitational settling (e.g., surface dust by vacuum).
  - Vacuum samples offer greater spatial and temporal coverage but may bias towards larger particles and robust pathogens.
- HVAC**
- Samples building HVAC filters or deploys active air samplers within ducts.
  - Facilitates unobtrusive access to building-wide samples, but environmental conditions may damage particles and lower recovery.



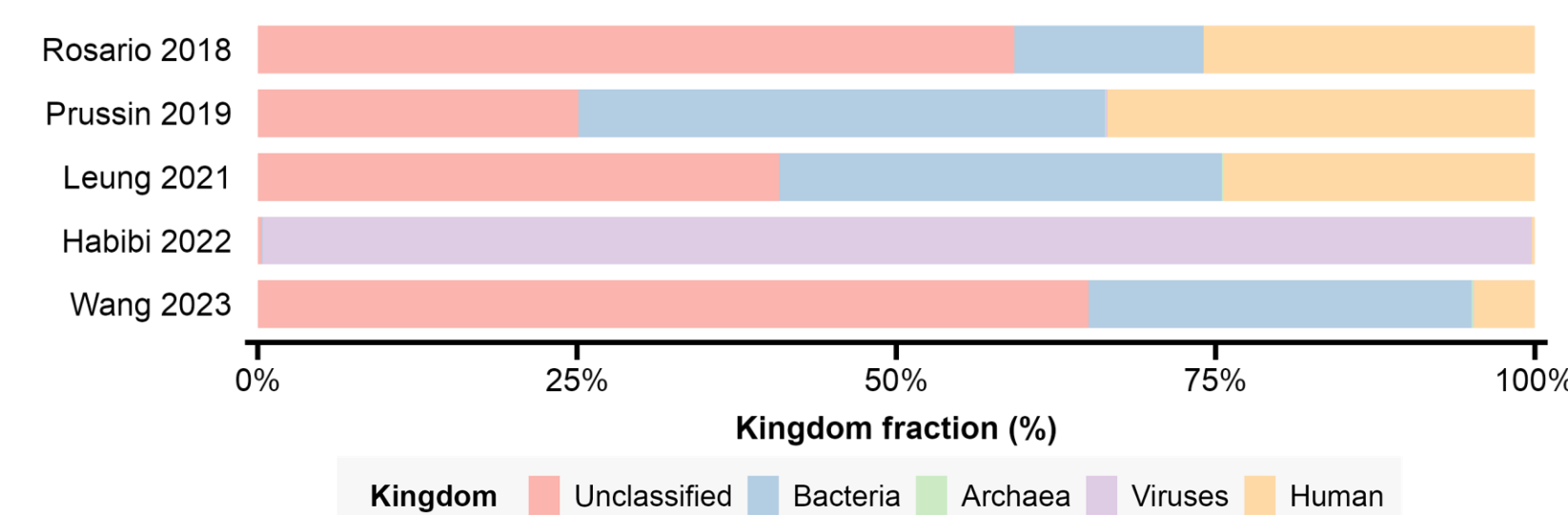
**Figure 2:** Capture mechanisms employed by different types of active air samplers.

## VIRAL CONTENT OF INDOOR AIR

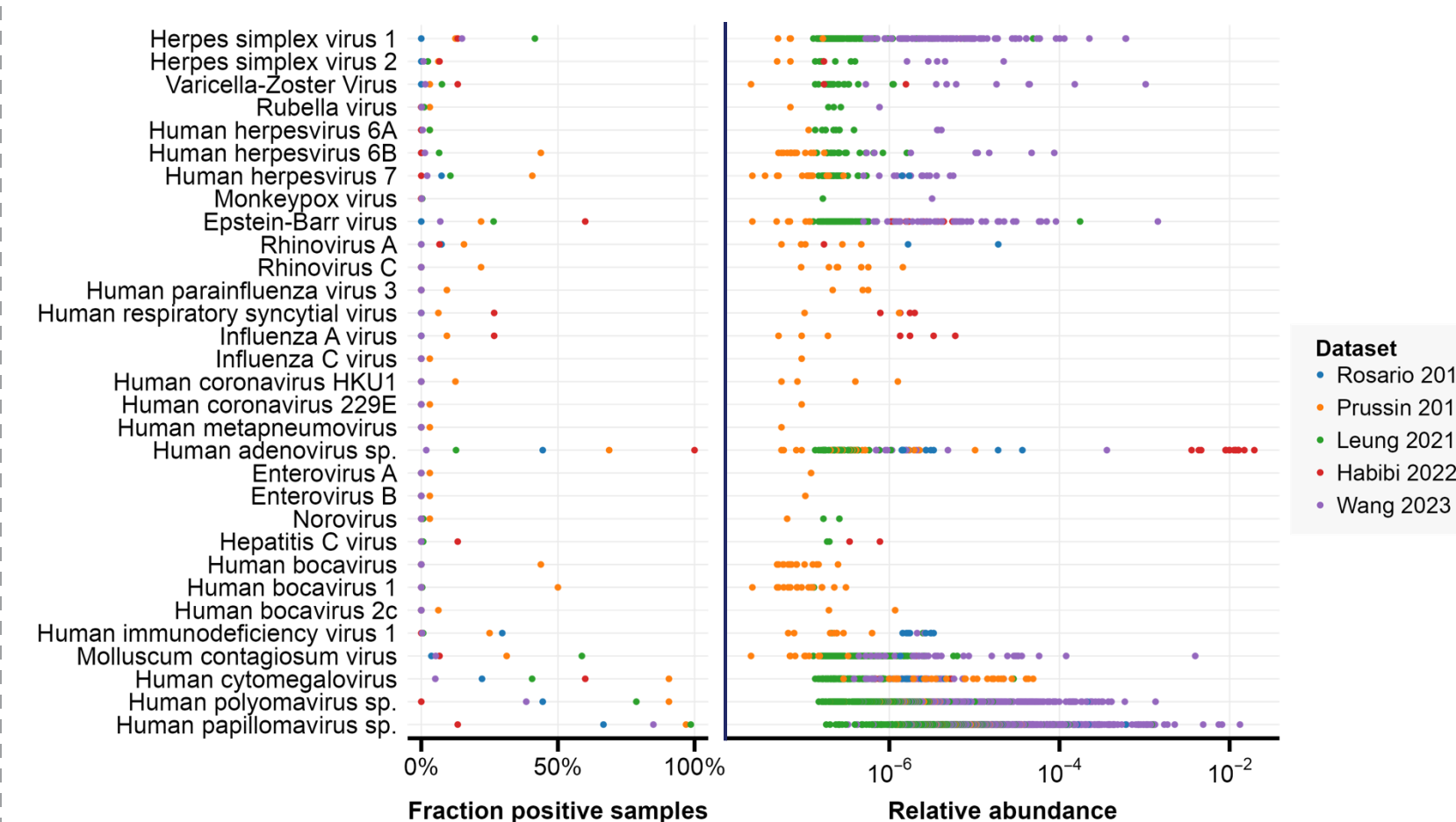
Study	Sample type	Location	Collection device	Reads	Samples	NA type
Rosario 2018	HVAC filter dust	Dorms	MERV 8 HVAC filter	18M	28	DNA+RNA
Prussin 2019	HVAC filter dust	Daycare	MERV 14 HVAC filter	470M	32	DNA+RNA
Leung 2021	Air	Public transit	SASS 3100 Dry Air Samplers	1.3B	294	DNA
Habibi 2022	Air	Hospital	Custom air sampler	18M	15	RNA <sup>†</sup>
Wang 2023	Surface dust	Homes	DUSTREAM Collector	330M	879	DNA

<sup>†</sup> Habibi et al. (2022) performed hybrid capture enrichment of 39 virus strains across nine viruses using the Celeomics Comprehensive Respiratory Virus Panel.

**Table 1:** Datasets included in our reanalysis of metagenomic sequencing data from air and dust samples. Note: NA = Nucleic acid.



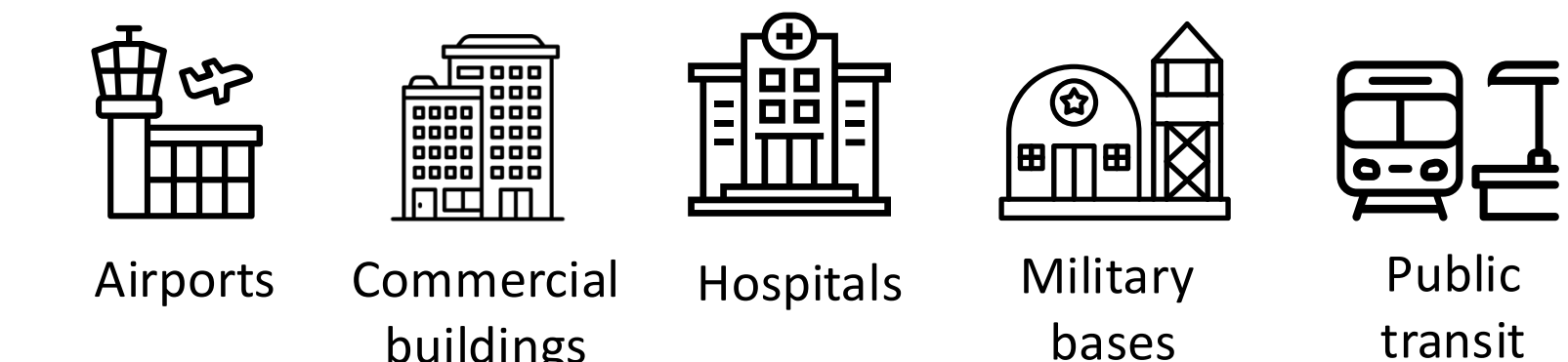
**Figure 3:** Kingdom-level composition of the metagenomic sequencing datasets described in Table 1. We use a custom taxonomic classification pipeline available from <https://github.com/naobservatory/mgs-workflow>.



**Figure 4:** Detection of selected human-infecting viruses across datasets. (Left) Fraction of positive samples per virus. (Right) Relative abundance in positive samples.

## PROMISING LOCATIONS

- Crowded locations with steady flow of new people.
- Areas enriched for epidemiologically significant demographics (e.g., international travelers, overseas military personnel, patients).



## CONCLUSION

- Indoor air sampling shows potential for early detection of viral pathogens, including from asymptomatic carriers.
- Challenges include low viral concentrations in air and need for improved submicrometer particle capture.
- Strategic implementation in high-traffic areas could significantly enhance biosurveillance capabilities.
- Future focus should include privacy-preserving techniques, optimizing HVAC and dust sampling, and integration with existing biodefense frameworks

## ACKNOWLEDGEMENTS

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