Open-source Intelligence Assessment of Air Pollutant Mixtures as a Threat to Force Health and Readiness at Military Bases in the United States

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Introduction

Chronic exposure to occupational air pollutants poses significant health risks that can undermine the readiness of the force through respiratory, cardiovascular, and sleep impairments and disease.

Health impacts of air pollution vary depending on the mixture, necessitating the characterization of individual components.

A VO2 Test. Photo: Spc. Nathan Thome.

Goal

To estimate annual mean ambient concentrations of 8 air pollutants at 859 U.S. Military facilities in 2023 and their potential impacts on health and readiness.

Methods

Data: We obtained mean air pollutant concentrations estimated by the Washington University Atmospheric Composition Analysis Group (V5.NA.05.02) derived from satellite, simulation, and monitor-based data for 2023 at 0.01° x 0.01° in (µg/m^3), including:

- Total particulate matter, diameter <2.5 µm ($PM_{2.5}$)
- Sulfate (SO_4^{2+})
- Nitrate (NO_3^-)
- Ammonium (NH_4^+)
- Organic matter (water soluble and non-soluble)
- Black carbon
- Dust

We created a risk score calculated as the sum count of air pollutants at high levels (in the top 10% across U.S. facilities or if total $PM_{2.5}$ exceeded the World Health Organization annual limit of 5 µg/m^3 (Range: 0 to 8).

We used Pearson correlations and principal components analysis to identify the most common air pollutant mixtures at U.S. Military facilities.

Results

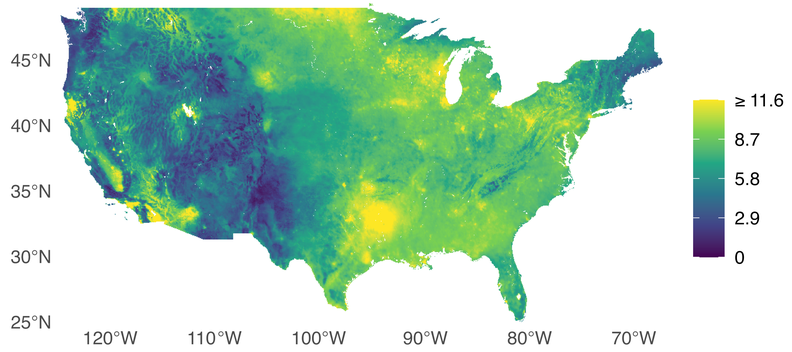

Figure 1: Annual mean $PM_{2.5}$ concentration (µg/m^3) across the U.S.; similar measurements are made by satellite for other air pollutants.

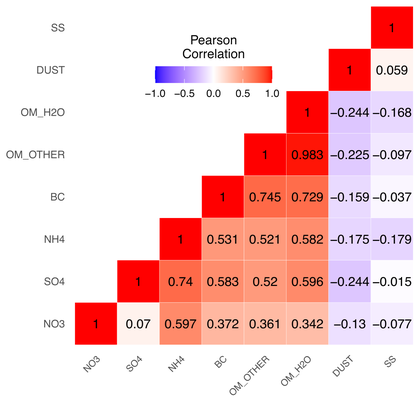

Figure 3: Two-way correlations among pollutants, the strongest were between:

A. Sulfate and ammonium
- High-temperature fuel combustion

B. Organic matter and black carbon (soot)
- Incomplete fuel combustion

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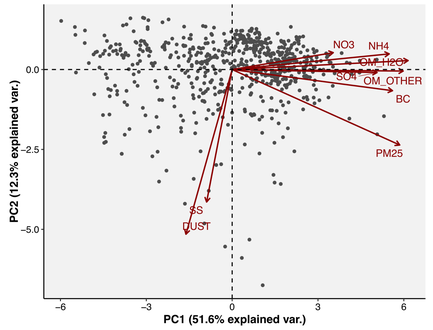

Figure 4: Cluster analysis across all pollutants suggested a common emissions source for half (51.6%) of the air pollution variation.

- Primary component (51.6%) is consistent with JP-8 combustion byproducts

- Secondary pollutant component pollutant explains 12.3% of air pollution variation and comprises dust and sea salt; likely in facilities in coastal or arid areas.

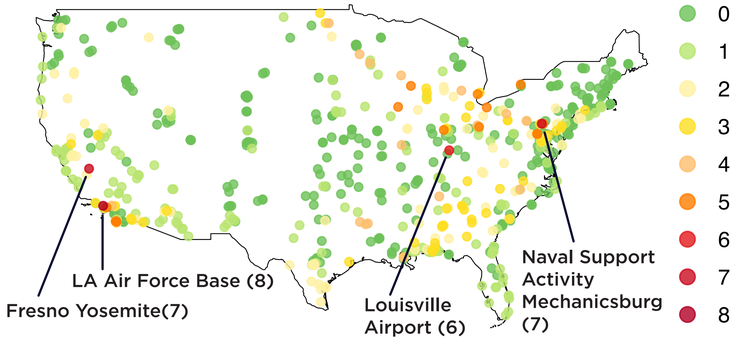

Figure 2: Air pollution 'risk score' for domestic U.S. Military facilities (count of pollutants measured in the top 10% or above WHO limits).

Conclusions

Air pollution at many military facilities was detected at levels high enough to impair lung function and impact force health readiness. Cluster analysis suggests that fossil fuel combustion may be largely responsible for these exposures and impacts.

Limitations

Our study used remotely estimated ambient air pollution, not data from outdoor on-site air monitors. We could not assess indoor air pollution exposures.

Future Directions & Implications

Electrification strategies could be used to mitigate chronic exposures during routine base operations, leading to a stronger and more resilient force:

- Plug-in hybrid-electric vehicles
- Modular vehicle power systems and storage
- Zero-logistics energy sources

Improving ventilation in close quarters, improving protective equipment, and conducting regular health screenings could also reduce health impacts.

DLH could link our findings to military health records data to understand how these air pollutants contribute to illnesses at U.S. Military facilities.