Military Environmental Epidemiology Symposium
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After Action Review

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Introduction

Held at Uniformed Services University on 22 April 2025, the inaugural Military Environmental Epidemiology Symposium (MEES) convened scientists studying health risks resulting from environmental and occupational exposures in military (DoD or VA) populations to review the state of the science, discuss challenges and opportunities in methodology (exposure assessment, study design, data structure/access), and foster collaboration and innovation

Executive Summary

The MEES convened leading experts to assess the current landscape of research resources and infrastructure, identify critical challenges, explore future opportunities, and discuss strategic directions for the military environmental epidemiology field. Discussions highlighted the significant contributions of ongoing large-scale studies, such as the Millennium Cohort Study and the Million Veterans Program (MVP), as well as case-control studies nested in the DoD Serum Repository (DoDSR) cohort, in understanding the long-term health impacts of military service and environmental exposures. Valuable sources of data and biospecimens for military environmental epidemiology research, such as the Defense Medical Surveillance System (DMSS), Military Health System Data Repository (MDR), and DoDSR were described. Key research areas, including investigations of excess risks for a variety of diseases in relation to exposures to burn pits, per- and polyfluoroalkyl substances (PFAS), jet fuels, Gulf War illness, and various occupational hazards, were highlighted. The Symposium also addressed substantial challenges in the field such as limitations in exposure data, difficulties in data access and sharing, concerns about data quality, the complexity of military exposures, and inherent methodological limitations.

To address these hurdles and advance the field, recommendations by speakers and participants emphasized the importance of leveraging existing data resources, capitalizing on advancements in omics technologies, advancing exposure assessment in the military, fostering interagency and academic collaborations, and applying new analytical tools such as artificial intelligence (AI) and machine learning (ML).

The Symposium concluded with a set of strategic recommendations focused on enhancing data integration and accessibility, improving exposure assessment methods, promoting interdisciplinary collaboration, engaging stakeholders, attracting new and early-career researchers, and proactively addressing emerging environmental health concerns relevant to the military.

1. State of Research in Military Environmental Epidemiology

1.1. Key Ongoing Studies and Resources and Their Contributions

The **Millennium Cohort Study**[1], established in 2001, represents the largest and longest-running Department of Defense (DoD) research endeavor focused on the health and readiness of the U.S. Armed Forces, having enrolled over a quarter of a million service members since its inception. The study gathers data through questionnaires administered every 3 to 5 years and links this information with comprehensive military records on deployment history, occupation, and health care and conditions. This integrated approach allows for a holistic evaluation of military service impacts, including the effects of deployments and occupational exposures, on the long-term mental and physical well-being of participants. The study's design, with its large number of participants and extended follow-up period, provides a unique platform for investigating the potential health consequences of military environmental exposures. Over the past two decades, research stemming from the Millennium Cohort Study has spanned an array of topics, including readiness and deployment, mental health, health-related behaviors, environmental exposures, physical health and injury, Veterans' health, financial well-being, and civilian reintegration.

The **Million Veterans Program (MVP)**[2], launched by the Department of Veterans Affairs (VA) in 2011, represents another important research undertaking in this domain. This large prospective cohort study focuses on elucidating how genes, lifestyle factors, military experiences, and exposures collectively influence the health and wellness of veterans. With an enrollment exceeding one million veterans, MVP is one of the world's largest programs dedicated to the study of genetics and health. The study involves the collection of genetic samples, coupled with detailed covariate data obtained through surveys, and the integration of exposure data to gain a comprehensive understanding of the factors affecting veterans' health. The aim of MVP is to translate these findings into tangible improvements in healthcare for veterans.

The **Defense Medical Surveillance System (DMSS)** is the central repository of medical and health-related surveillance data for the DoD, containing data from many sources.[3] It contains data on more than seven million past and current military service members since 1990. DMSS records include demographic and military characteristics and military and medical experiences throughout a service member's career. DMSS data is utilized in not only environmental epidemiology research, but also advances biomedical research across many areas. Additionally, DMSS data analyses are disseminated through Medical Surveillance Monthly Reports (MSMR), summarizing frequencies, rates, and trends of medical events in active duty service members.

Established in 1989, the **DoD Serum Repository (DoDSR)**[4], currently housed at the Defense Health Agency's Armed Forces Health Surveillance Division (AFHSD), is a vital resource for military environmental epidemiology research. The DoDSR contains over 74 million serial blood-derived serum specimens obtained from active-duty and reserve service members. Initially established for HIV screening purposes, the DoDSR's mission has expanded to include the storage of pre- and post-deployment serum samples. Linked with the DMSS, the DoD Cancer Registry and other health databases, the DoDSR facilitates sera-epidemiologic investigations conducted by DoD researchers. The availability of these serially collected serum samples, coupled with available demographic, occupational, and medical data, provides a powerful tool for retrospective studies examining the potential risks of environmental exposures.

The **Long-Term Impact of Fuel Exposure (LIFE) Study**, a collaborative effort between the VA and the DoD, strives to understand the long-term health effects associated with occupational jet fuel exposure in military personnel. This study was mandated, in part, by the Honoring our Promise to Address Comprehensive Toxics (PACT) Act (PL 117-168). The prospective LIFE study is designed to monitor changes in symptoms and the incidence of long-term health effects among exposed service members. This research is particularly important given the potential for various routes of exposure to jet fuels in military occupations.

1.2. Significant Research Focus Areas

The Symposium highlighted several prominent areas of research within military environmental epidemiology. **Burn pits,** a common method of waste disposal in military operations in areas like Iraq and Afghanistan, have become a significant focus due to concerns about the long-term health consequences of exposure to their emissions. Research is actively investigating the potential links between burn pit exposure and the development of respiratory and cardiovascular diseases, as well as various types of cancer. The PACT Act has further amplified this focus by establishing presumptive conditions for certain illnesses in veterans who were exposed to burn pits during their service.

Per- and polyfluoroalkyl substances (PFAS) constitute another critical area of research. The widespread use of PFAS-containing firefighting foams on military installations has led to significant environmental contamination, raising concerns about potential health effects in exposed personnel and surrounding communities. Research has linked PFAS exposure to a range of health issues, including altered immune and thyroid function, liver disease, lipid dysregulation, kidney disease, adverse reproductive and developmental outcomes, and cancer. Researchers at

DoD, the National Institutes of Health (NIH), and other institutions are conducting testing for PFAS in DoDSR sera to better understand the potential health impacts of exposure.

The potential health effects of **jet fuels** are also receiving considerable attention. Military personnel may encounter jet fuels through fueling aircraft, maintaining equipment, or due to accidental spills. While some research suggests possible associations between jet fuel exposure and issues such as nervous system effects, mental health problems, respiratory symptoms, and certain cancers, more research is needed to clarify these connections.

Gulf War illness (GWI), a chronic multi-symptom disorder affecting veterans of the 1990-1991 Gulf War, remains a subject of ongoing research. Studies have indicated potential links between GWI and exposure to neurotoxins, including low levels of sarin, as well as pesticides and pyridostigmine bromide, which were present in the theater of operations. Current research aims to further elucidate the biological pathways involved in GWI and to develop effective treatments for veterans.

Finally, **occupational exposures** encountered during military service encompass a broad spectrum of potential hazards, including chemicals, radiation, noise, and physical stressors. Research seeks to identify specific occupational exposures across various military roles and settings and to determine their potential associations with different health outcomes. The VA's development of the Veteran Military Occupational & Environmental Exposure Assessment Tool (VMOAT) reflects the growing recognition of the need for comprehensive assessment of these exposures.

1.3. Prevalent Research Methodologies Employed

The Symposium also highlighted the diverse methodologies employed in military environmental epidemiology research. **Cohort studies** are a cornerstone of this field. The Millennium Cohort and Million Veterans Studies are prime examples of very large cohort studies being conducted among military servicemembers and Veterans.

Case-control studies, in particular those nested within the DoDSR cohort (often combining resources like the DoDSR and DoD Cancer Registry), have been utilized successfully to investigate rare diseases and chronic diseases with long latency periods.

Biomarker analysis, involving the measurement of biological markers in serum samples, provides objective measures of exposure and early indicators of health effects. The DoDSR offers a valuable resource for this type of research, enabling measurement of past exposures.

Omics approaches, such as genomics , epigenomics, transcriptomics, proteomics, and metabolomics, are increasingly being applied to understand the complex interactions between genes, environment, and health at a molecular level. These technologies hold immense potential for identifying novel biomarkers, elucidating disease pathways, and developing targeted prevention and treatment strategies for environmentally-related illnesses.

2. Critical Challenges in Military Environmental Epidemiology

Despite the significant progress in military environmental epidemiology, participants identified several critical challenges.

2.1. Limitations in Exposure Data

There is a scarcity of comprehensive, accurate exposure data that has been linked to large study populations in the military. We lack detailed historical and real-time environmental monitoring data for many deployment locations and time periods relevant to military service due to the nature of many military missions, which present logistical

difficulties. Furthermore, historical records of chemical use, spills, and other environmental hazards on military bases and during deployments are often incomplete or inconsistent. Inferring exposures through military occupation codes fails to capture the substantial variability in exposures experienced by individual service members based on their specific job roles and locations.

2.2. Data Access and Sharing Issues

Historically, difficulties in integrating and sharing health and exposure data between the DoD and the VA have impeded the ability to conduct longitudinal studies that follow service members from enlistment through their time as veterans. This is changing though with recent, successful efforts to merge DoD and VA data, as evidenced by the LIFE study, for example. Moreover, external academic researchers and collaborators often face hurdles in accessing data for independent analysis, potentially slowing the pace of research and limiting the diversity of scientific perspectives.

2.3. Data Quality Concerns

The quality and reliability of available data presents concerns. Self-reported exposure and health information from service members may be subject to recall bias and other forms of reporting bias. Additionally, the quality and completeness of data can vary across databases and time periods, making it challenging to combine and compare information from multiple sources.

2.4. Complexity of Military Exposures

The nature of military service often involves exposure to a complex mixture of occupational and environmental agents. Disentangling the specific health effects of individual exposures within these complex mixtures poses a significant methodological challenge. Furthermore, the timing, duration, and intensity of exposures can vary considerably depending on the service member's military occupation, deployment location, and specific missions undertaken.

2.5. Methodological Challenges

Several methodological challenges complicate research. The **Healthy Deployer Effect** refers to the phenomenon that individuals who are deployed tend to be healthier than their non-deployed counterparts, which can potentially mask the negative health effects of deployment-related environmental exposures when comparing these groups. Additionally, many military cohorts, such as the initial enrollees in the Millennium Cohort Study, were relatively young at the time of enrollment. This presents a challenge for studying the development of chronic diseases with long latency periods that may not manifest until later in life. Additionally, many environmentally-related diseases, including certain cancers, have long latency periods. This necessitates long-term prospective studies to fully capture the health consequences of military environmental exposures, which are resource-intensive and time-consuming.

3. Opportunities for Advancing the Field

Despite the challenges, numerous opportunities can be leveraged to advance research in military environmental epidemiology.

3.1. Leveraging Rich Existing Data Resources

The field benefits from several rich existing data resources which hold immense potential for future research. These include the **Military Health System (MHS) Data Repository (MDR)** and the **DMSS**, which contain extensive

health and deployment data on military personnel. The **DoDSR** is another invaluable resource, offering a unique opportunity for retrospective biomarker studies. The MVP has amassed a database of genetic, lifestyle, and military exposure information from over one million veterans. Furthermore, the ongoing development of the **Individual Longitudinal Exposure Record (ILER)** promises to support integration of environmental exposure data with individual health records. Enhanced integration and accessibility of these data resources are crucial for facilitating research on the long-term health effects of military environmental exposures.

3.2. Advancements in Omics Technologies and Biomarker Discovery

The rapid advancements in omics technologies provide powerful tools for gaining a deeper understanding of the biological responses to environmental exposures. These technologies offer the potential to discover novel biomarkers of exposure, and early indicators of disease, which can lead to more precise risk assessment and the development of targeted interventions.

3.3. Application of New Technologies like AI/ML for Data Analysis

The application of new technologies such as artificial intelligence (AI) and machine learning (ML) offers promising avenues for analyzing large and complex datasets within the DoD and VA. These methods have the potential to identify exposure-disease patterns, predict health risks with greater accuracy, and personalize interventions in ways that traditional statistical methods may not be able to achieve.

4. Strategic Ways Forward

The Symposium concluded with a discussion on strategic ways forward to address the challenges and capitalize on promising opportunities for advancing research in military environmental epidemiology.

4.1. Enhancing Data Integration and Accessibility

A primary recommendation was to prioritize the development and implementation of ILER, which would facilitate linkage of environmental exposure data with individual health records across both the DoD and the VA. Concurrently, establishing clear, standardized protocols for data sharing and access for authorized researchers was deemed essential. A more centralized and readily accessible data infrastructure is considered fundamental to enabling more comprehensive and efficient studies on the long-term health effects of military environmental exposures.

4.2. Enhancing Exposure Assessment Methods

Participants emphasized the need for continued investment in the development and refinement of **job exposure matrices** that can provide semi-quantitative estimates of exposures to specific agents of concern based on military occupational and deployment histories. Increased utilization of both historical and contemporary **environmental monitoring data,** integrated with advanced geospatial technologies, was highlighted as a step towards reconstructing past exposure scenarios with greater precision. Furthermore, exploring the feasibility of **personal exposure monitoring technologies** for military personnel to capture individual-level exposure data in appropriate contexts was recommended.

4.3. Fostering Interdisciplinary Collaborations and Working Groups

The Symposium advocated for the creation of formal mechanisms to support interdisciplinary and interinstitutional collaborations among epidemiologists, toxicologists, clinicians, data scientists, environmental engineers, and other relevant experts from the DoD, VA, and academic institutions. The establishment of focused

working groups dedicated to specific environmental exposures (e.g., burn pits, PFAS, jet fuels) or health outcomes (e.g., respiratory diseases, cancers) was also proposed to facilitate enhanced knowledge sharing and streamline research efforts.

4.4. Engaging with Stakeholders

Establishing effective and consistent communication channels and feedback mechanisms to actively engage with service members, veterans, clinicians, and DoD/VA leadership was identified. Understanding their concerns and available resources is paramount in guiding research priorities. Furthermore, developing clear and accessible strategies for communicating research findings to stakeholders is crucial for informing policy and improving healthcare and interventions.

4.5. Attracting and Training New Researchers

Recognizing the growing need for expertise in this area, participants emphasized the importance of investing in education, training, and collaborations to attract and cultivate a new generation of researchers specializing in military environmental epidemiology.

4.6. Focusing on Emerging Environmental Health Concerns Relevant to the Military

The Symposium highlighted the need to proactively identify environmental health threats and concerns. This includes exposures to microplastics, new formulations of firefighting foams (including fluorine-free alternatives), noise from equipment and other ambient sources, and exposure to novel ammunitions.

5. Conclusions

The Inaugural MEES provided a valuable platform for experts to summarize the current state of research, examine existing challenges, identify areas for improvement, and collaboratively outline strategic directions for the future. The ongoing contributions of large-scale longitudinal studies, coupled with focused research on specific environmental exposures, are steadily enhancing our understanding of the health risks faced by military personnel. Discussions throughout the day also underscored the need to address limitations in exposure data, improve data accessibility and quality, and incorporate sophisticated methodologies to analyze complex exposure data. The discussed strategic ways forward, emphasizing enhanced data infrastructure, improved exposure assessment, interdisciplinary collaboration, stakeholder engagement, and a proactive approach to emerging threats, provide a roadmap for the field to continue its role in protecting the health and well-being of service members. The increased focus and resources driven by legislation like the PACT Act signal a pivotal moment for military environmental epidemiology, offering unprecedented potential to translate research into meaningful improvements in policy and healthcare for current and former service members.

References

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