APPENDIX AVAILABLE ON
THE HEALTH EFFECTS INSTITUTE–ENERGY WEBSITE

Communication 1

HUMAN EXPOSURE TO UNCONVENTIONAL OIL AND GAS DEVELOPMENT: A LITERATURE SURVEY FOR RESEARCH PLANNING

HEI-Energy Research Committee

Appendix B. Research Priorities and Study Design Elements Recommended by Workshop Participants

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APPENDIX B

RESEARCH PRIORITIES AND STUDY DESIGN ELEMENTS RECOMMENDED BY WORKSHOP PARTICIPANTS

APPENDIX B

HEI-Energy hosted two public workshops where experts presented summaries of relevant literature and they and other workshop participants shared priorities for research to fill knowledge gaps about human exposure left by the current body of UOGD literature. Table B-1 summarizes recommendations from workshop participants. More information about the workshops can be found at *www.hei-energy.org*.

Table B-1. Workshop Participant Recommendations: Research Priorities and Study Design Elements

Theme	Description
Overarching Considerations	
Considers variability across oil and gas-producing regions	Many factors contribute to variability in potential exposures among regions: - Geology, chemical composition of the resource, terrain, and meteorological conditions - Industry practices, regulations, and technologies used at each phase of development and production and differences between old and new technologies - Presence of non-UOGD sources. Research should be broadly relevant given these factors and should be adaptable to evolving practices and conditions.
Feasible	Well-designed research should be feasible, with a defined timeline, budget, and scope.
Addresses community concerns	Research should consider both community concerns and expert priorities. Research teams should leverage partnerships with communities to identify which research topics and data would be of value.
Leverages industry partnerships	Research teams should leverage relationships with industry partners to better understand differences in industry practices between operators and over time that may affect study results.
Informs regulatory decision-making	Research should produce results that are actionable and useful to regulators, including determination of setback distances. Research should collect information about variability in strength of regulatory enforcement among regions, how strength of enforcement may impact chemical or non-chemical exposures, and efficacy of current mitigation techniques (e.g., noise barriers). Research topics that have already been addressed by regulation should not be research priorities.
Considers actual versus perceived risk	Research should prioritize exposure pathways and chemicals for study that previous literature suggests might posed a health risk. Research should consider, but should not prioritize, topics for research based solely on perceived health risk.
Data Collection and Transparency	
Makes use of available data	Given finite financial resources, researchers should consider data mining and consolidating publicly available data to understand nationwide exposures. Leveraging existing data through data mining is a cost-effective method to determine where data gaps remain and how to prioritize future research.
Applicable to other studies	The research should be designed so that in addition to achieving study objectives, results are also useful for future epidemiology studies or risk assessments.
Collects air-and water-quality data and supporting metadata	To fill important knowledge gaps, several types of data collection were recommended, including: - Chemical measurements in air and water - Personal monitoring - Noise, light, and odor levels - Fate and transport information - Operator time–activity data (e.g., on-site operations, types of equipment on-site, and what conditions are present during the measurement) - Human time–activity data
Provides data transparency	All data should be made available in an easily accessible and comprehensible form.

Table B-1. Workshop Participant Recommendations: Research Priorities and Study Design Elements

Theme	Description
Priority Exposure Pathways and Agents	
Prioritizes study of air over water exposure pathway	- Chemical emissions to air are expected to occur at every phase of development and production, whereas water contamination is expected to occur less frequently and under accidental conditions. Therefore, study of potential emissions to air may be more critical than the study of water contamination. In particular, studies include assessment of emissions from diesel engines and flowback. - Study of potential water contamination should occur in conjunction with studies of air quality, especially potential exposures related to groundwater reuse of produced water.
Considers chemical toxicity and mixtures	Research should prioritize inclusion of specific chemicals by reviewing existing chemical screening work. Studies should also consider chemical mixtures. *In vivo* and animal toxicology work can be useful models to examine potential exposure to mixtures unique to UOGD.
Focuses on agents known to have an adverse impact	Studies should focus on chemical and non-chemical agents that can be quantified and on agents with the highest toxicity and potential for harm. Suggested agents include benzene, toluene, ethylbenzene, and xylene (BTEX), black carbon, high molecular-weight polycyclic aromatic hydrocarbons (PAHs), diesel exhaust, fine and ultrafine particulate matter, other criteria pollutants, and noise (at high and low frequencies). However, investigators should not ignore the study of chemicals for which there are limited toxicity data.
Includes study of agents that are unique to UOGD	Studies should focus on agents that are unique to UOGD and can be used as markers of UOGD releases.
Considers multiple exposure pathways	Studies should address total exposure by multiple pathways of exposure.
Sampling Methods	
Uses standardized methods	Research methods and protocols should be standardized to allow for inter-study comparability across regions. Following HEI's model of ensuring high-quality data, research should also undergo standard quality assurance and quality control audits and third-party data reviews.
Uses relevant and high-quality instrumentation	Regardless of the sampling method, the instrumentation should be able to detect chemicals known to be emitted from UOGD (rather than "catch-all" instrumentation that measure suites of chemicals) and at detection limits below health-relevant standards.
Considers magnitude, frequency, and duration	Research should involve collection of data at frequencies and durations that are relevant to human health and allow for assessments of both acute (short-term or peak) and chronic (low and long term exposure) exposure. Sampling should capture diurnal and seasonal variability.
Uses relevant measurement approaches for noise, light, and air studies	Several types of instrumentation and models can be used to quantify exposure, including satellite data, mobile monitoring, wearable personal monitors, low-cost sensors, and paired indoor-outdoor residential sampling. - Mobile monitoring approaches can find and measure the plume, rather than waiting for the plume to come to the monitor under low-wind speed conditions. - Ambient measurements should be paired with personal exposure measurements. - Fixed, high-quality monitors should collect ambient measurements near the emission source, including meteorology. - Measurement approaches should also include measurements of agents dispersed regionally.

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Theme	Description
Analytical Methods	
Distinguishes between UOGD and other natural and anthropogenic sources	Studies should employ sampling and analytical methods to distinguish UOGD impacts from those of other potential sources of exposure, including conventional oil and gas development and non-UOGD related traffic.
Uses source-apportionment techniques	Source-apportionment studies would be useful to identify the specific UOGD equipment or operation that may lead to exposures.
Incorporates modeling	Studies should include measurement and modeling components to allow for prediction of levels of chemical or non-chemical agents under various conditions.
Populations	
Focuses on community exposures	Investigators should focus on community-based exposure in areas where people live, and not on accidental exposures. Investigators should also consider effects of exposure on vulnerable populations. The populations to be studied may differ depending on the type of exposure under investigation (e.g., regional versus local air quality).
Compares data to exposure surrogates used in epidemiology studies	Studies should include a component that evaluates current exposure assessment methods used in the epidemiology literature (e.g., distance to a well as a surrogate for exposure) against measured or modeled data.