Assessing Mixtures Risks for Cleanup and Stewardship

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Introduction

The U.S. Department of Energy (DOE) is responsible for addressing contamination from past research, production, and disposal activities at over 100 sites and facilities across the country. Use of emerging science to assess risks for these facilities is the key to defining appropriate solutions. Safely managing contamination is a priority to protect workers in the near term, and sustained protection is a priority for local communities over the long term.

The Department conducts its environmental management program with input from a number of groups who have expressed concern about the safety of DOE sites over time and the possible conversion of some lands to other uses. In general, past facility activities and disposal operations have contaminated about 10% of the total collective area of DOE sites while surrounding lands have served as buffer zones. Portions of several sites have been released for other uses, such as wildlife preserves. Soil, surface water, and groundwater have been contaminated in most instances, and on-site waste disposal is targeted for many sites. Wastes and contamination that will remain in the environment are at the heart of ongoing future use and long-term management deliberations. For this reason, oversight groups and local citizens are scrutinizing the risk assessments being conducted to support decisions on final cleanup and long-term stewardship.

Contaminants exist throughout the world not as individual chemicals but as combinations. The standard risk assessment process broadly applied to support cleanup decisions for contaminated sites is based on single-chemical analyses that do not consider joint toxicity. That is, possible nonadditive effects (commonly termed synergistic or antagonistic) of multiple exposures to multiple chemicals are not generally addressed. The U.S. Environmental Protection Agency (EPA) has been developing a process to assess risks of multiple chemicals (EPA 1990, 2000), but it is not yet being applied to address complex contaminated sites.

To ensure continued health protection at DOE sites, various parties have asked that the risk assessments being conducted consider multiple chemicals, media, exposures, and receptors – including unique subgroups – over large spaces and extended time frames. Some have explicitly requested that potential synergism be evaluated, as well as health endpoints beyond the critical effect. In addition to the focus on long-term protection, recent catastrophic events that could cause widespread contaminant releases (fires and earthquakes) have heightened concerns about multiple-chemical, multiple-route exposures and cumulative effects.

Work Description

This paper describes the development of an initial approach for evaluating mixtures at an example DOE site. The overall scope involves a nested screening process aimed at identifying those contaminants and scenarios for which such an assessment is appropriate, integrating toxicity information, and preparing supporting material to improve how information is communicated. The primary focus of the work to date has been the development of a screening approach for mixtures assessment. A Health and Environmental Availability/Risk Toxicity (HEART) database has also been created to support the analysis. A brief fact sheet that highlights key mixtures issues and defines the terms has also been prepared, as have a number of contaminant-specific health risk fact sheets.

Results

The nested screening process for a mixtures risk evaluation at a contaminated site begins with a scoping step to determine whether such an evaluation is warranted. This step includes reviewing site conditions and potential contaminant release scenarios, as well as stakeholder requests. For the example DOE site, stakeholder input was a main impetus behind the assessment. Part of the review of site conditions involves assessing the specific contaminants present (type, concentration, and toxicity) and those that may be produced in the future through transformations such as physical decay (radionuclides) or biodegradation (organic chemicals). This phase targets those contaminants of health concern that could exist together, either in the environment at the point of human exposure or within the body upon intake and internal distribution; both locations would provide an opportunity for joint effect.

When the scoping step indicates a mixtures risk assessment is appropriate, then consistent conceptual models are developed to link data across media and likely receptors. At this stage, the major contaminant sources and the release and transport mechanisms are identified to assess the potential for location overlap. Contaminant distribution in the environment is evaluated by considering concentrations in different media over time, which includes grouping contaminants by key characteristics such as soil-water partition coefficients (to represent environmental mobility), with a preference for site-specific data.

Together with the review of environmental and toxicity data, an evaluation of how the land and resources are being used and likely will be used is important for determining key receptors and appropriate exposure scenarios. For the example DOE site (a portion of which was recently designated as a national monument), the assessment could involve a ranger and recreational visitors as well as subsistence visitors, notably Native Americans involved in activities such as fishing, hunting, and gathering. Factors that could inform the receptor assessment include unique characteristics such as age, gender, body burden, disease status, genetic polymorphisms, and diet/lifestyle, to the extent this information is available.

For the toxicity assessment portion of the process, potential contaminant overlap in systems/organs within the body is determined. This phase includes an individual concentration-toxicity screen and identification of both the critical effect (the system/organ effect observed at the lowest dose in the toxicity study) and secondary effects (those seen at higher doses, e.g., in other organs), where this information is available. Also summarized is retention within the body, to assess the opportunity for overlap in time. Recovery is another relevant factor, including the time to system/organ recovery and the functional level regained. Unfortunately, human toxicity data relevant to environmental exposure levels are limited, as these data are typically extrapolated from results for test animals given much higher doses. For this reason, the screening process includes a step for placing chemicals of concern for which relevant mixtures data are not currently available on a watch list that can be revisited when new information becomes available.

A number of figures have been prepared to illustrate key elements of the screening analysis. These include depictions of distributions within the body and relative toxicities by route of exposure for a study set of chemicals and radionuclides. Individual fact sheets have also been prepared for more than 30 contaminants, to describe what is known about potential health effects from exposures and to serve as the foundation for grouping to assess the opportunity for internal overlap. These fact sheets and supporting figures have been well received.

Conclusions and Discussion

A mixtures assessment process is needed to frame the evaluation of potential health risks associated with multiple contaminants in the environment, especially for DOE sites where local communities expect safe conditions to be maintained for hundreds to thousands of years. Agencies such as the EPA have been working for decades to define safe levels and set standards for protecting human health from environmental contamination. However, the current assessment approach considers each chemical individually rather than as they actually occur – mixed with everything else. Further, resultant risk predictions are largely based on guesswork and models because relevant measurements simply do not yet exist. While assessment methods and toxicity data for chemical mixtures continue to evolve, they have not yet been applied to risk assessments for cleanup sites.

In fact, an understanding of mixtures health effects is important with regard to DOE cleanup and stewardship decisions. Without a focus on priority health and environmental concerns, life-cycle costs could be unnecessarily and unmanageably high given the wide range of contaminants present at these sites and the long time frame over which they will require management. At the moment, mixtures research is in its infancy and has primarily focused on the effects of diesel particulates in laboratory animals. Furthermore, the few true mixtures studies that are available do not accurately reflect environmental or "field" conditions. Nevertheless, community groups have expressed concern about the assurance of long-term protection from multiple contaminants at DOE sites. Responding to these concerns with information currently available can help limit the costs incurred by continued open-ended discussions on the issue and help focus the uncertainty management effort needed for the stewardship phase.

To address this need, an initial approach for evaluating mixtures risks at contaminated sites that accommodates our current state of knowledge has been developed. This study demonstrates that a targeted screening process can be applied as a first step toward addressing stakeholder questions about the risks of multiple contaminants, which until now have remained largely unanswered. The process can also serve to frame the information needed to conduct more fully quantitative assessments as the science continues to evolve.

References

U.S. Environmental Protection Agency, 1990, Technical Support Document on Health Risk Assessment of Chemical Mixtures, EPA/600/8-90/064.

U.S. Environmental Protection Agency, 2000, Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures, EPA/630/R-00/002.

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