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The effect of misunderstanding the chemical properties of environmental contaminants on exposure beliefs: A case involving dioxins

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HIGHLIGHTS

- We surveyed residents of a community with known dioxin contamination.
- The survey explored residents' mental models of dioxins and exposure pathways.
- Many community residents appear not to understand that dioxins are hydrophobic.
- Mistrust of government predicts beliefs that dioxins are present in water.
- Beliefs about dioxins in water predict beliefs about water-based exposure pathways.

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ABSTRACT

Chemical properties of contaminants lead them to behave in particular ways in the environment and hence have specific pathways to human exposure. If residents of affected communities lack awareness of these properties, however, they could make incorrect assumptions about where and how exposure occurs. We conducted a mailed survey of 904 residents of Midland and Saginaw counties in Michigan, USA to assess to what degree residents of a community with known dioxin contamination appear to understand the hydrophobic nature of dioxins and the implications of that fact on different potential exposure pathways. Participants assessed whether various statements about dioxins were true, including multiple statements assessing beliefs about dioxins in different types of water. Participants also stated whether they believed different exposure pathways were currently significant sources of dioxin exposure in this community. A majority of residents believed that dioxins can be found in river water that has been filtered to completely remove all particulates, well water, and even city tap water, beliefs which are incongruous with the hydrophobic nature of dioxins. Mistrust of government and personal concern about dioxins predicted greater beliefs about dioxins in water. In turn, holding more beliefs about dioxins in water predicted beliefs that drinking and touching water are currently significant exposure pathways for dioxins. Ensuring that community residents' mental models accurately reflect the chemical properties of different contaminants can be important to helping them to adjust their risk perceptions and potentially their risk mitigation behaviors accordingly.

1. Introduction

When community residents are informed that environmental contamination has occurred, they face significant challenges in understanding what that information means for their community, their property, and their personal or family's health. Among the questions that community residents often have are what is the contaminant, where does it reside in the environment, how and when might I interact with it, and what might it do if it gets inside me? Answers to all of these questions are necessary to enable residents to identify potential

Abbreviations: DLCs, Dioxin-like compounds; CDDs, Chlorinated dibenzo-p-dioxins; CDFs, Chlorinated dibenzo-p-furans; PCBs, Polychlorinated biphenyls; UMDES, University of Michigan Dioxin Exposure Study; CPOD, Community Perceptions of Dioxins.

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harms that a contamination might cause and to identify steps that could be taken to mitigate them.

Note, however, that all of the above questions depend not only on understanding *that* contamination has occurred and *where* it originally occurred but also on understanding the particular *characteristics* of the contaminant in question. Specific chemical and physical properties of contaminants can lead them to aggregate in certain places within the environment and not others and enter the human body through certain pathways and not others.

Good examples of environmental contaminants whose chemical characteristics significantly impact its interactions with both the environment and people are dioxins and dioxin-like compounds (DLCs). DLCs are usually defined as the 29 specific congeners from three classes of compounds (chlorinated dibenzo-p-dioxins (CDDs), chlorinated dibenzo-p-furans (CDFs), and polychlorinated biphenyls (PCBs)) that have been assigned toxic equivalency factors by the World Health Organization and that are sometimes collectively referred to as 'dioxins' (Van den Berg et al., 2006). While PCBs were once intentionally manufactured, other DLCs (CDDs and CDFs) are unintentional byproducts of various processes, including combustion and chemical manufacturing (U.S. Environmental Protection Agency, 2012), and have been identified as the primary contaminants in multiple recent high-profile environmental exposure incidents (Akhtar et al., 2004; Baughman and Meselson, 1973; Bertazzi et al., 2001; Landi et al., 1998). They are of particular concern for public health because they are known or suspected of causing cancer and other health effects and they persist in the environment and in the body (U.S. Environmental Protection Agency, 2012).

One of the critical characteristics of DLCs is that they are lipophilic and highly hydrophobic, aggregating in fats and oils and having negligible solubility in water (Agency for Toxic Substances and Disease Registry, 1998). This fact about DLCs is of critical importance for understanding fate and transport in the environment and which pathways of human exposure are potentially significant. For example, dioxins will adsorb onto the organic carbon fraction of soil or river sediment but will not be present within water that has had all suspended particles removed (Agency for Toxic Substances and Disease Registry, 1998). As a result, whether community residents understand the lipophilic and hydrophobic nature of dioxins is likely to have a major influence on residents' perceptions of both exposure potential and risk from water. To document such effects, however, requires broadly assessing the mental models that community residents may hold regarding environmental contaminants in general and dioxins in particular.

The mental models approach to risk communication is specifically designed to explore how target populations (e.g., community residents) make sense of information about potential health risks (Morgan et al., 2002). It posits that people have pre-existing conceptual models that include their conceptual understandings of the chemical or physical properties of contaminants. These models tend to guide people's beliefs about risk in situations that contain considerable uncertainty, such as many environmental contamination situations.

Mental models research studies generally attempt to distinguish those concepts, facts, or beliefs that are already well understood by most members of the community affected by a risk from misconceptions or factual omissions that might inhibit effective understanding of the health risk and implementation of actions needed to manage that risk. If misconceptions or omissions are identified as common in the target population, risk communications can then be developed to correct people's understandings. In other words, the approach focuses on providing information to correct critical beliefs without overwhelming people with concepts they already know and understand. Past research has used the mental models approach to examine lay understanding of topics as diverse as laws of motion, vaccinations, high-frequency radiation from base stations for mobile communication, chemical risk protection in the workplace, perchloroethylene (PCE) used in dry cleaning, radon, and low-frequency electromagnetic fields (Atman et al., 1994; Bostrom et al., 1992, 1994; Cousin and Siegrist, 2010; Cox et al., 2003; Downs et al., 2008; Kovacs et al., 2001; Morgan et al., 1990; Gentner and Stevens, 1983).

The Community Perceptions of Dioxins (CPOD) study used a three-phase mental models approach to document the mental models of dioxins held by residents of the communities of Midland and Saginaw counties, Michigan, USA. Elevated levels of DLCs were discovered in the sediments and soils of the Tittabawassee River floodplain located in Midland and Saginaw in the mid-to-late 1990s, and earlier in the City of Midland (Garabrant et al., 2009a). The congeners identified have been traced back to the Dow Chemical Company, located in Midland, which is believed to have historically emitted dioxins from their facilities, primarily through waste discharges to the Tittabawassee River and aerosol emissions from incineration (Garabrant et al., 2009a, 2009b). In 2004–5, the University of Michigan Dioxin Exposure Study (UMDES) gathered blood samples from residents, samples of their residential soil and house dust, and information about their behaviors that could influence their exposure. This information was then analyzed to determine whether and under what circumstances environmental concentrations of dioxins were correlated with resident body burdens (Demond et al., 2012; Garabrant et al., 2009a, 2009b), and the results were communicated to stakeholders and community residents through a variety of methods, including the study web site, public meetings, media contacts, and confidential communications to study participants (Franzblau et al., 2011).

Our research goal was to explore community residents' mental models of dioxins, and in particular whether those models are congruent or divergent with experts' understanding of the hydrophobic nature of dioxins, as a case study of the conceptual challenges that community residents face when trying to make sense of communications about environmental contamination exposures. This paper reports data from the quantitative phase of data collection, which involved a large scale mailed survey of community residents of Midland and Saginaw counties that was designed to target mismatched beliefs identified in the initial qualitative phases of this project. In the present manuscript, we focus specifically on water-related beliefs, documenting the proportion of residents who believed that dioxins are present in different sources of water and the relationship of these beliefs to beliefs that water-related exposure pathways may be significant sources of dioxin exposure. Based on these findings, we discuss how future risk communications about environmental contaminants such as dioxins might be improved by clarifying how chemical properties can dictate which exposure pathways most require attention and which are comparatively safe.

2. Material and methods

2.1. Preliminary qualitative findings

In a preliminary qualitative phase of this research, we interviewed 5 experts from academia, government, and community environmental groups to develop an expert model of dioxin contamination, exposure and health effects. We then compared their models to those derived from interviews with 50 lay community members to identify key differences.

These interviews used a non-leading protocol to systematically map out each expert's or resident's mental model of dioxins without introducing new words or ideas (Community Perceptions of Dioxins Study, 2010). The interviews began with broad, open-ended questions (e.g., "Could you tell me about dioxins and any risks they pose?") and followed up with probing questions (e.g., "You mentioned dioxins can cause cancer. Can you tell me more about that?") to gain more information on responses that were unclear or warranted further explanation. Probes focused on knowledge of exposure processes (e.g., how and where dioxins may be concentrated), effects processes, risk assessment and management (e.g., mitigation strategies), and risk comparisons.