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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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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

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Appendix A. Supplementary data

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chemical properties of different contaminants can be important to helping them to adjust their risk perceptions and potentially their risk mitigation behaviors accordingly.

Keywords

Community environmental exposure; Dioxin-like compounds; Mental models; Risk communication; Risk perception

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 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.

The expert interviews were aggregated into a consensus model that outlined the basic pathways that dioxins follow through the environment, from their creation and emission to their persistence and distribution in the environment (e.g., concentration in river sediment), intake by humans (e.g., ingestion) and subsequent health effects. This model was similar in its broad structure to those identified in previous research on workplace exposure situations (Cox et al., 2003) but included more detail about where dioxins might or might not be found. This "where are the dioxins?" question is of critical importance in historical environmental contamination situations in which environmental processes may have resulted in significant movement of the contaminant over time. We also note that expert agreement about higher-level concepts did not imply agreement about details. For example, our experts agreed that health effects of dioxin exposure can exist even as they disagreed regarding the type and dose-response relationships of those effects.

We analyzed the community resident interviews through a focused qualitative coding process, as described by Morgan et al. (2002) that involved identifying each instance of respondent speech that corresponded to an expert model node, a particular connection between expert model nodes, or novel concepts identified from the layperson interviews. We used these codes to identify interview segments that were either congruent or incongruent with the concepts in the consensus expert model.

In particular, this process identified multiple statements by community interviewees indicating that they believed that the dioxins that had been historically discharged into the Tittabawassee River were now dissolved in local river and ground water supplies. This was evidenced by statements such as "the water is saturated" and "I think it just kind of mixes in with the water like everything else." This led to fear about the magnitude of potential exposure through tap water because "we're drinking it every day; we're washing our hands in it every day." Participants also questioned whether dioxins could be removed from contaminated water and saw dredging the river as ineffectual. However, the small sample involved with these extended interviews limited our ability to draw population-level

conclusions. To further explore the prevalence of lay beliefs about the presence of dioxins in water, we designed the mailed survey that is the subject of this report.

2.2. Participants

We surveyed two groups of residents of Midland and Saginaw counties: former participants of the UMDES (“UMDES”) and non-participants (“non-UMDES”). Results from a control group from Jackson and Calhoun counties are not reported here because those participants were not asked questions used in this analysis about the specific local water sources of historical concern in Midland and Saginaw counties. However, this design did allow us to explore whether participation in the UMDES study affected residents’ mental models. After excluding households with residents who had previously completed the mental model interviews (N=50), all remaining UMDES participants in Midland/Saginaw (N=913) were included in UMDES sample. Of these, 62% were residents of the flood plain or near flood plain areas of the Tittabawassee River (as defined by the UMDES). The non-UMDES sub-sample was selected using unused sample replicates from the UMDES (Garabrant et al., 2009a). The CPOD study was given access to these address lists, identified residents’ names and phone numbers through publicly available databases, and then randomly selected a sample of 1000 non-UMDES residents for use in the CPOD study. Approximately 50% of these surveys were sent to residents of the floodplain or near flood plain. Eight non-UMDES participants were added after they completed surveys on behalf of former UMDES participants who were either deceased (n=3), in long-term care facilities (n=2), or had moved (n=3). In addition, four non-UMDES participants were discovered to be UMDES participants and were relabeled. Eligibility criteria included: (i) 18 years of age and older; (ii) one or more years of residence in current home; (iii) residence in region of interest; and (iv) ability to complete a mailed questionnaire.

2.3. Recruitment

Participants received a pre-survey postcard in July–August 2011. A few weeks later, we mailed surveys and a \$5 cash pre-completion incentive to all sample members except those who had indicated (via the postcard or telephone) that they did not wish to participate or whose postcards had been returned as undeliverable. Non-respondents received telephone calls (if number was known) and duplicate surveys (without additional incentive). We sent a \$10 Visa® gift card to participants upon receipt of a completed survey. All methods received Institutional Review Board approval prior to subject recruitment, and all CPOD data are protected by a Certificate of Confidentiality.

2.4. Survey content

2.4.1. Knowledge about dioxins—A large section of the survey included true/false statements to assess community members’ knowledge, including beliefs related to potential water-borne sources of exposure to dioxins. Specifically, we tested whether respondents knew that dioxins can be found in soil and sediment in or near the Tittabawassee River and that dioxins are likely to be left behind on someone’s property (via sediment) if the Tittabawassee River floods. We also tested whether respondents believed that elevated levels of dioxins could be found in local well water, tap water, and/or completely filtered river water and whether they believed that casual skin contact with river water would significantly increase dioxin exposure. Specific question wordings are shown in Table 1.

2.4.2. Significant sources of dioxin exposure—Another section asked respondents to check whether or not they believed various pathways were a significant source of dioxin exposure in the past and/or in the present and which pathway they believed to be the largest

current source of dioxin exposure. We focus here on beliefs regarding the pathways of drinking water and touching water (e.g., swimming).

2.4.3. Other survey content—The survey included questions (see Appendix 1 for specific items) about community members' level of concern about dioxins and their feelings about government, industry, and related environmental concerns (e.g., perceptions of trust in government, concerns about withholding of information, and perceived control over health risks) that were adapted from three validated scales (Johnson and Chess, 2003; Kaiser Family Foundation, 2000; Peters and Slovic, 1996). It also included several questions developed by the study team assessing respondents' specific satisfaction with information about dioxins. We collected demographic data, including race/ethnicity, gender, age, education, subjective numeracy (Fagerlin et al., 2007), number and age of any children, length of residence in home, and whether the participant had ever worked for a chemical company. We also asked participants to recall whether they had received two previous communications distributed by the UMDES study.

2.5. Data entry

Each survey was double-entered and inconsistencies resolved. We removed duplicate surveys from the same household (n=5), a survey whose respondent reported an age of seven, and surveys from eleven non-UMDES participants who were unintentionally sent an incorrect survey version.

2.6. Data analysis

We created an aggregate beliefs about dioxins in water scale equal to the number of water-specific beliefs held (filtered river water, well water, tap water, and skin contact; range: 0–4), with omitted responses conservatively assumed to be cases of disbelief. We also created a scale of feelings about mistrust of government (see Appendix 1), representing a mean response after rescaling each item to range from 1 to 5. Lastly, we used participants' mean response on six questions about perceived worry (all on a 1–5 scale, partial missing data imputed) as a measure of personal concern about dioxins (see Appendix 1).

All analyses were conducted in Stata Version 12 (Stata Corporation, 2011) and all p-values were calculated using two-tailed tests of significance. We used linear regression models to identify significant predictors of the beliefs about dioxins in water scale. Baseline predictors included demographic variables, while a second model added as predictors the mistrust of government scale, the personal concern about dioxins scale and a binary variable measuring whether or not participants stated that they were very familiar with dioxins. This represents the full set of participant characteristics measured in the survey. In a follow-up analysis, we used logistic regression models to determine whether these variables and the beliefs about dioxins in water scale would predict whether respondents believed that drinking water or touching water is currently a significant source of dioxin exposure. All regressions used multiple imputation procedures with chained equations (as implemented in Stata 12's *mi, chained* command set) and ten imputations to impute missing values for age, gender, education, and numeracy score.

3. Results

3.1. Participant characteristics

A total of 893 residents of Midland and Saginaw counties completed the survey, including 444 previous participants in the UMDES. The response rate for UMDES participants was 60.1% and for non-UMDES was 51.2%, as calculated using the American Association of

Public Opinion Research's RR2 formula (American Association for Public Opinion Research, 2011).

Study participants had an average age of 58 years old, ranging from 20 to 95 years old, 48% were male, and 77% reported having children of any age. Consistent with community demographics, 93% were white, and 59% had lived in their current home for over 15 years. Approximately 11% reported working for a chemical company in an "expert" capacity, i.e. management, office or administrative support, production, or professional. Participants had an average subjective numeracy score of 4.59 (range: 1–6; Cronbach's $\alpha=0.87$). In terms of education, 29% of participants had no more than a high school diploma, 36% had completed some college, an associates degree, or professional training, 22% had a Bachelor's degree, and 13% had a Master's degree or higher. A majority (56% of the non-UMDES subgroup and 65% of the UMDES subgroup) were residents of the Tittabawassee River flood plain or near flood plain. Only 40% recalled having received at least one of the brochures reporting UMDES findings sent out in 2006 and 2011, and 39% said they were very familiar with dioxins.

3.2. Beliefs about dioxins in water

Table 1 presents responses to the true/false questions addressing the lipophilic and hydrophobic nature of dioxins. Participants had many beliefs that were congruent with experts' models. For example, 96% of respondents believed it is true that elevated levels of dioxins can be found in the sediment of the Tittabawassee River. However, in regard to the contamination of the river water itself and other water sources, many participants had incongruent beliefs. For example, 79% of respondents believed that elevated levels of dioxins can be found in water from the Tittabawassee River even after all soil and sediment had been removed.

The four questions included in our beliefs about dioxins in water scale were moderately correlated with each other (pairwise correlations ranged from 0.24 to 0.36). When aggregated, the resulting scale had a mean of 2.32 (range: 0–4; std. dev.=1.25) and moderate reliability (Cronbach's $\alpha=0.62$).

Many demographic variables had significant bivariate associations with the beliefs about dioxins in water scale (Table 2). Male gender, older age, higher education, higher numeracy, and greater familiarity with dioxins were all associated with lower water scale scores, indicating that these individuals felt that dioxins were less prevalent in different categories of water. Recalled receipt of UMDES findings brochures was also associated with lower beliefs about dioxins in water, but participation in the UMDES was not. Lastly, high mistrust of government (scale Cronbach's $\alpha=0.73$) and high personal concern about dioxins (scale Cronbach's $\alpha=0.94$) were both significantly associated with higher beliefs about dioxins in water.

These associations generally persisted in multivariate linear regression models (Table 3), with a few exceptions. As shown in Table 3 (first column), age, gender, education, numeracy, and recall of the UMDES brochures are all significant independent predictors of beliefs about dioxins in water. However, when we added the mistrust of government scale, familiarity with dioxins variable, and personal concern about dioxins scale, age, gender, and education all became non-significant. Note, however, that individual numeracy remained a significant predictor, highlighting its relevance as a unique construct distinct from education. Note also that the effect size of both mistrust of government and personal concern about dioxins are both substantial. A person with maximally high mistrust and personal concern would be expected to be more than two full points higher on our 0–4 point beliefs about dioxins in water scale. An illustrative demonstration of this effect is shown in Fig. 1.

3.3. Beliefs about drinking or touching water as sources of exposure

Fig. 2 shows that higher values on our beliefs about dioxins in water scale was correlated with greater likelihood of believing that either drinking or touching water is a significant source of dioxin exposure (both p -values < 0.001). As shown in Table 4 (first column), age, gender, and education are all significant independent predictors of believing drinking water is a significant source of dioxin exposure currently. However, when we added the beliefs about dioxins in water scale, education and gender became non-significant. Even after controlling for demographics, the beliefs about dioxins in water scale is highly related to beliefs that water-based exposure pathways are significant. Note also that high mistrust of government, high personal concern about dioxins, and less familiarity with dioxins are also associated with believing that drinking water is currently a significant source of exposure to dioxins.

4. Discussion

Our results show that most Midland/Saginaw community residents believe that dioxins can be found in river water that has been filtered to completely remove all particulates, well water, and even city tap water, and appear to not appreciate the hydrophobic nature of dioxins. These beliefs directly correlated with beliefs that touching water and drinking water are currently significant pathways of dioxin exposure in this community. They are also in conflict with extensive evidence that public water supplies and private well water sources in Midland/Saginaw do not contain significant amounts of dioxins (Michigan Department of Environmental Quality, 2003; Weston Solutions, 2009a, 2009b, 2010).

These findings underscore the critical importance of not merely informing affected populations that contamination has occurred and where contaminants have been found in the environment but about the agent's chemical and physical properties and how those properties influence its behavior in the environment. Midland/Saginaw residents have heard over and over that industrial discharge *into the river* was the original source of most of the present dioxin contamination in river sediments and floodplain, and that as a result "the river" is contaminated. It is hardly surprising that residents have thereby concluded that it may be the river water itself that is tainted. Yet, in this case, dioxins that were discharged from the Dow Chemical Plant were likely quickly bound to particles in the river and accumulated within sediment at the bottom and banks of the river. To the extent that dioxin contamination has subsequently spread to other areas, it has been when the sediment was disturbed or spread during flooding events or through intentional transfer of riverbank soil to other areas (Franzblau et al., 2009). Only by clarifying the way that dioxins interact with both water and particulates can we hope to help community residents understand why the fact that dioxins were initially put into the river water does not imply that they stayed there over time.

This finding is conceptually similar to that of Bostrom et al. (1992) regarding lay people's mental models of radon risk. A key property of radon is that it has a relatively short half-life and decays in a matter of days. Understanding this property of radon facilitates motivation to undertake radon abatement measures (because lowering the degree of new contamination quickly lowers the rate of exposure), while failure to understand this property was observed to be a barrier to action. Our contribution, therefore, is to reinforce the importance of ensuring that affected populations understand the properties of contaminants and to draw attention to a different property (i.e., water solubility) that has relevance to a broad range of contamination situations.

One approach to alerting people to the fact that dioxins are hydrophobic might be to draw the (admittedly imperfect) analogy that dioxins are more like oil than they are like water.

Most people know that oil separates from water either by floating to the surface or clumping with particles and sinking to the bottom. Fitting dioxins into the “like oil” part of this pre-existing schema could evoke a large number of evidence-congruent associations about dioxins among community residents. Such associations would not only mitigate concerns about drinking water supplies and casual river water contact but increase awareness of the potential problems involved with transporting riverbank soil, disturbing packed river sediment, or eating bottom-feeding fish.

Our findings are tempered by several limitations. First, Midland/ Saginaw counties are relatively homogenous with higher levels of education and less racial diversity than many other regions in the United States. These differences may limit our ability to generalize to other communities affected by dioxin contamination (e.g., Anniston, Alabama) that have radically different racial and education distributions. Second, we acknowledge some possibility of non-response bias. Residents who chose to participate in CPOD study activities may be more concerned about dioxins than other residents are. Yet, despite such potential motivations to learn about dioxins, many CPOD study participants clearly did not grasp the hydrophobic nature of dioxins.

5. Conclusions

One of the basic principles of effective risk communication is to enable the target audience to draw by themselves the same conclusions that experts have drawn. In Midland, it has been insufficient to simply tell people that dioxins are in the soil and not the river water, because it is likely that people assume cross-contamination will occur unless they understand that the chemical properties of dioxins prevent this. Taken broadly, the CPOD data suggest that public health risk communications need to explain how the properties of different contaminants lead them to behave in particular ways in the environment and hence have specific pathways to human exposure. Only by clarifying these properties can we help community residents distinguish between hydrophobic dioxins and, for example, hydrophilic 1,4-dioxane, which often enters groundwater supplies near contaminated sites (Abe, 1999; U.S. Environmental Protection Agency, 2006), and adjust their mental models, risk perceptions, and risk mitigation behaviors accordingly.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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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

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.

Fig. 1.
Predicted score on the beliefs about dioxins in water scale based on selected participant characteristics.

Fig. 2. Proportion of CPOD study participants who believed that drinking or touching water is a significant source of dioxin exposure, by score on the beliefs about dioxins in water scale.

Table 1

Participant beliefs about survey items related to the hydrophobic nature of dioxins.

Item	% believe statement is true
<i>Congruent beliefs</i>	
Elevated levels of dioxins can be found in the sediment at the bottom of the Tittabawassee River. (Answer: true)	96.3%
Elevated levels of dioxins can be found in the soil on the banks of the Tittabawassee River. (Answer: true)	93.0%
If the Tittabawassee River floods onto someone's property, it is likely to leave behind dioxins. (Answer: true)	84.9%
<i>Incongruent beliefs^a</i>	
Elevated levels of dioxins can be found in water from the Tittabawassee River even after all soil and sediment has been removed. (Answer: false)	79.3%
Elevated levels of dioxins can be found in well water in the Midland/Saginaw area. (Answer: false)	70.4%
Elevated levels of dioxins can be found in the city water supply ("tap water") of Midland and/or Saginaw. (Answer: false)	30.8%
Skin contact with the Tittabawassee River water (for example, swimming) can significantly increase the amount of dioxins in a person's body. (Answer: false)	53.7% ^b

^aThese items were used to create our beliefs about dioxins in water scale.

^bRates of agreement with this statement were significantly different between UMDES participants (57.3%) and non-UMDES participants (49.9%), $p=0.028$.

Table 2Bivariate relationships between participant characteristics and the beliefs about dioxins in water scale.^a

Participant characteristics	Scale mean	p-value
Age 60 or older		0.003
No	2.44	
Yes	2.19	
Gender		<0.001
Female	2.51	
Male	2.14	
Education ^b		<0.001
High school diploma or less	2.61	
Some college, associates degree, professional training	2.41	
Bachelor's degree (BA, BS)	2.03	
Master's degree or higher	2.07	
Numeracy score (2 groups)		<0.001
Low (below median)	2.48	
High (above median)	2.16	
Residence in floodplain or near flood plain		0.046
No	2.43	
Yes	2.25	
UMDES group		0.372
Non-UMDES	2.36	
UMDES	2.28	
Receipt of 2006/2011 UMDES findings brochure(s)		<0.001
Did not receive either	2.45	
Received either or both	2.14	
Worked in production or management for chemical company		0.138
No	2.34	
Yes	2.15	
Familiar with dioxins (missing data changed to 0)		<0.001
Not very	2.45	
Very	2.12	
Mistrust of government scale ^{b,c}		<0.001
High (upper third)	2.68	
Average (middle third)	2.48	
Low (lower third)	1.85	
Personal concern about dioxins scale ^{b,d}		<0.001
High (upper third)	2.75	
Average (middle third)	2.46	
Low (lower third)	1.87	

^a Scale range: 0–4; higher means reflect answering more questions as true.

^bSignificance based on univariate ANOVA instead of t-test.

^c1–5 scale, average of 10 items, see Appendix 1.

^d1–5 scale, average of 6 items, see Appendix 1.

Table 3

Multivariate linear regressions (using multiple imputation) predicting scores on the beliefs about dioxins in water scale.

Parameter	Base model n=878		Adding familiar with dioxins, mistrust of government scale, and personal concern about dioxins scale as predictors n=832	
	Coef. [95% C.I.]	p-value	Coef. [95% C. I.]	p-value
Age (per 10 years)	−0.10 [−0.16, −0.04]	0.001	−0.05 [−0.11, 0.01]	0.078
Male	−0.26 [−0.43, −0.10]	0.002	−0.14 [−0.31, 0.02]	0.090
Education (1–4)	−0.16 [−0.25, −0.06]	0.001	−0.05 [−0.14, 0.05]	0.345
Numeracy score (1–6)	−0.13 [−0.21, −0.04]	0.004	−0.12 [−0.20, −0.03]	0.008
Residence in river floodplain or near floodplain	−0.07 [−0.24, 0.10]	0.403	−0.06 [−0.23, 0.10]	0.442
UMDES participation	0.02 [−0.16, 0.21]	0.809	0.08 [−0.10, 0.26]	0.365
Recalled 2006 or 2011 UMDES brochures	−0.25 [−0.43, −0.06]	0.011	−0.18 [−0.37, 0.01]	0.058
Worked in production or management for chemical company	−0.14 [−0.39, 0.12]	0.288	−0.02 [−0.27, 0.22]	0.857
Mistrust of government scale (1–5)	–	–	0.37 [0.20, 0.54]	<0.001
Familiar with dioxins	–	–	−0.12 [−0.29, 0.05]	0.171
Personal concern about dioxins scale (1–5)	–	–	0.26 [0.17, 0.35]	<0.001

Table 4

Multivariate logistic regressions (using multiple imputation) predicting belief that drinking water is a significant current source of dioxin exposure.

Parameter	Base Model n=846		Adding beliefs about dioxins in water scale n=839		Adding mistrust of government, familiar with dioxins, and personal concern (n=797)	
	O.R. [95% C.I.]	p-value	O.R. [95% C.I.]	p-value	O.R. [95% C.I.]	p-value
Age (per 10 years)	0.82 [0.74, 0.91]	<0.001	0.85 [0.76, 0.95]	0.003	0.89 [0.79, 1.00]	0.047
Male	0.66 [0.49, 0.87]	0.004	0.74 [0.55, 1.01]	0.056	0.90 [0.65, 1.23]	0.501
Education (1–4)	0.80 [0.68, 0.94]	0.006	0.87 [0.73, 1.03]	0.109	0.99 [0.82, 1.19]	0.911
Numeracy score (1–6)	0.94 [0.81, 1.09]	0.435	1.01 [0.86, 1.18]	0.943	1.01 [0.85, 1.19]	0.929
Residence in river floodplain or near floodplain	0.83 [0.62, 1.12]	0.224	0.86 [0.63, 1.18]	0.351	0.92 [0.67, 1.28]	0.630
UMDES participation	1.03 [0.74, 1.42]	0.867	1.03 [0.73, 1.46]	0.858	1.08 [0.75, 1.56]	0.670
Recalled 2006 or 2011 UMDES brochures	0.79 [0.57, 1.09]	0.150	0.88 [0.62, 1.25]	0.472	1.04 [0.71, 1.51]	0.853
Worked in production or management for a chemical company	0.68 [0.44, 1.07]	0.094	0.70 [0.43, 1.13]	0.143	0.72 [0.43, 1.20]	0.209
Beliefs about dioxins in water scale (0–4)						
0	–	–	(Reference)	–	(Reference)	–
1	–	–	1.78 [0.94, 3.38]	0.076	1.46 [0.75, 2.85]	0.264
2	–	–	2.74 [1.50, 5.01]	0.001	2.06 [1.10, 3.85]	0.025
3	–	–	5.32 [2.95, 9.58]	<0.001	4.08 [2.21, 7.54]	<0.001
4	–	–	11.06 [5.75, 21.28]	<0.001	7.45 [3.71, 14.95]	<0.001
Mistrust of government scale (1–5)	–	–	–	–	1.59 [1.11, 2.27]	0.011
Familiar with dioxins	–	–	–	–	0.56 [0.40, 0.78]	0.001
Personal concern scale (1–5)	–	–	–	–	1.31 [1.09, 1.58]	0.004