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Communicating with the public about environmental health risks: A community-engaged approach to dialogue about metal speciation and toxicity

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1. Introduction

Over the past 30 years, a series of experiences and events has influenced a family of related topics known variously as public knowledge of science, civic scientific literacy, public engagement with science, and scientific outreach. Here we review some of these developments to ask how they might be relevant to contemporary environmental health sciences research and recommend adoption of principles of health communication and community engagement in order to advance our efforts for environmental restoration, conservation, stewardship, and sustainability.

In 1985, the Royal Society published a report titled "The Public Understanding of Science" (The Royal Society, 1985). It recommended that scientists learn how to communicate and that nonscientists listen to them. If this happened, then nonscientists would support government funding for scientific research. There was no sense that the public might fruitfully contribute to scientific policy or implementation. Rather, it would passively receive a message delivered from the scientific community. This report generated two reactions. First, the scientific community took public understanding more seriously than before and launched various initiatives in this spirit (Felt, 2000). Second, an opposition to the report crystallized (e.g., Wynne, 1992), and the term "deficit model" was coined as a shorthand for the thinking behind the report. The deficit model treated adults as passive information consumers so that "the basic measure of progress in public understanding of science is taken to be how much more science people can be made to understand" (Ziman, 1992, p. 14).

This approach may cause the public to doubt the communication and decisions made by the "experts." Clear, culturally appropriate, and community-engaged communication about environmental issues is critical to help engage communities in important dialogue about their health risks and potential protective factors (Best et al., 2014; Ellis et al., 2014; Friedman et al., 2014a; Janmaimool and Watanabe, 2014), despite being infrequently used for environmental concerns compared with other public health issues. Community engagement is a type of public participation that involves people in problem-solving or decision-making processes. The Centers for Disease Control and Prevention (CDC) defines it as "the process of working collaboratively with groups of people who are affiliated by geographic proximity, special interests or similar situations with respect to issues affecting their well-being" (CDC, 2011, p. 3). Community-based participatory research (CBPR) has emerged as a strategy to work together in partnership with high-risk populations and other community stakeholders to ensure their engagement with the development and dissemination of health messages as well as bidirectional dialogue between scientists and the community to increase knowledge and literacy and promote preventive behaviors among participants and stakeholders (Greiner et al, 2014; Hebert et al., 2009; Wallerstein and Duran, 2010). We present an example of the complexities of environmental health sciences research in the area of metal speciation and toxicity and provide specific recommendations for community-engaged communication and related research with diverse audiences.

2. Complexities of communicating the science of metal pollution

The example we present is related to Superfund research—the US federal government's environmental program created under the

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Comprehensive Environmental Response, the Clean-up and Liability Act to address uncontrolled and the abandoned hazardous waste sites (US Environmental Protection Agency [USEPA], 2013a, 2013b). Based on the latest Superfund Remedy Report from the EPA (USEPA, 2013a, 2013b), lead (Pb), arsenic (As), hexavalent chromium (Cr(VI)), mercury (Hg), cadmium (Cd), and copper (Cu) are among the top ten frequently occurring pollutants in Superfund contaminated sites. Such metals are key pollutants of concern because they can be easily accumulated in organisms and may be highly toxic. There are also many potential impacts on human health from these environmental exposures (McDermott et al., 2012). For example, Pb can damage children's central nervous system and cause learning difficulties and behavioral changes (Finkelstein et al., 1998); As has been shown to cause liver damage, skin disease, diabetes, and cancer (Tchounwou et al., 2004); and Hg can damage kidneys and the central nervous system which cause memory loss and hearing loss (Martinez-Finley and Aschner, 2014). Due to agricultural activities and discharge of industrial wastes and other processes, heavy metals are produced in large amounts, and these metals can be accumulated in, for instance, fish and shellfish from various environmental compartments (Alina et al., 2012). Seafood is the product with the second highest imbalance of trade for the US behind oil, underscoring the need for global standardization of regulatory limits for toxic chemicals such as toxic metals to ensure uniform safety around the world (NOAA Fisheries, 2014). Given the high nutritional value in fish and shellfish, there is huge global consumption of seafood, bringing attendant risks for human health from the co-ingested metals.

Due to these significant health concerns, the USEPA (2007), the World Health Organization (WHO, 2006), and the European Food Safety Authority (EFSA, 2006) have suggested acceptable intake levels of these heavy metals, with intake based on total metal consumption (mg) divided by body weight (kg). However, it is well understood that total metal concentration does not correlate well with toxicity (Allen, 1993; Amiard et al., 2008) but that it is mediated by a variety of processes. For instance, chemical speciation (the chemical form or distribution of forms of the metal), dynamic behavior (chemical kinetics and mass transport), and bioavailability/bioaccumulation all can play a role in the toxicity of metals. The relationships between toxicity and the other factors mentioned are often non-linear, non-monotonic, and multi-factorial. Simple examples include (i) methyl mercury (MeHg) is often of more concern than inorganic mercury because it penetrates the blood–brain barrier more easily (Baldi, 1997), (ii) the inorganic form of As is often more toxic than the organic form (James, 2012) and (iii) Cr(VI) is more toxic than Cr(III). The uptake of metals by aquatic organisms and their toxic effects has been explained by chemical equilibrium-based models such as the free-ion activity model (FIAM) (Morel, 1983) and the biotic ligand model (BLM) (Di Toro et al., 2001), which is used in the US to regulate metals in the environment. However, such model developments are simplifications of real ecosystems where dynamics and mass transport are important (Slaveykova and Wilkinson, 2005). More specifically, in Superfund sites, the binding of metals to naturally occurring nanoparticle phases has been explored (Plathe et al., 2010), with significant impacts on mobility which will lead to changes in bio-uptake and toxicity.

Similarly, in food, metal speciation has also been examined. For example, As speciation is dominated by As(III)–thiol complexes in rice bran and endosperm, while there are significant speciation differences between white and brown rice (Meharg et al., 2008). Thus, metal speciation and related factors are very important when we evaluate metal toxicity, as these examples illustrate and understanding metal exposure to humans from the environment is hugely complex. The difficulty in communicating how such factors may impact on toxicity and their balance with nutritional factors is obvious.

Despite the beneficial nutrition of shellfish, there is risk from ingestion due to accumulation of trace metals (Goldhaber, 2003), which is itself strongly dependent on the poorly understood processes sketched briefly above. Due to these potential risks and the potential to pass the risks to the developing fetus, US and UK government agencies suggested that pregnant women limit seafood intake to 340 g or 3 servings per week (UKCOT, 2002; USEPA, 2004). The recommendation for public consumption, therefore, is a single number which subsumes these complex and incompletely understood processes described. This simplification is perhaps sufficient to maintain public health but precludes individuals' and communities' informed decision making and other important benefits of an engaged society.

3. Adopting principles of health communication and community engagement for environmental health sciences research

As can be seen from the example provided, the communication of such scientific issues is certainly no trivial matter, with many uncertainties, complexities, and potentially conflicts of interest. Research guided by sound science principles should utilize a “precautionary approach” (Recuerda, 2008) to address uncertainty by using the best available knowledge to protect society today and in the future while also engaging and involving the public to evolve an “adaptive management framework” (Arvai et al., 2006) and bring new and improved scientific understanding of an environmental issue to formulate better protection of the ecosystem and of the health of our communities.

People care very much about the health of their environment and about whether environmental conditions will affect their own heath and the health of their families. These environmental issues are further complicated by legal questions: if a condition in an environment is harming a population, then who is responsible for the harm, will those who are responsible be held accountable, who is responsible for communicating with the public about this harm, and how will this information be communicated? (Eisenman et al., 2007). Using effective communication strategies and health information technology to improve health outcomes and to achieve health equity is a key goal of the US Department of Health and Human Services *Healthy People 2020* (2010). Within this goal is an objective focused specifically on improving the health literacy of the population. Nutbeam (1998) defined health literacy as “the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand, and use information in ways which promote and maintain good health” (p. 357). Zarcadoolas and colleagues (2005) expanded the way we consider health literacy, stating that individuals with adequate health literacy should be able to “participate in the ongoing public and private dialogues about health, medicine, scientific knowledge and cultural beliefs” (p. 196). They proposed a multi-dimensional literacy model that also focuses on science literacy, civic literacy, and cultural literacy and that aligns nicely with the importance of the public's participation and engagement and democratic decision making in health and science focused research and practice.

Community engagement is a strong value and fundamental practice of environmental health sciences in support of public health. The importance of engaging the community is grounded in the belief that the public has a right to participate. The public health community believes that by using “collective intelligence” and working together, community leaders and public health officials will more accurately identify problems and develop more elegant and effective solutions. Also community conflict can be minimized if residents have had a chance to “buy into” the process. Specifically, within the Superfund program, for example, community engagement and research translation cores were established to support research initiatives and ensure authentic collaborations with communities and clear dissemination of findings.

Community-engaged studies focused on how to improve communication and messaging about health are on the rise (Best et al., 2014; Friedman et al., 2009, 2012b). For example, working collaboratively with community and clinical partners in the planning, recruitment, implementation, and evaluation of health and cancer education messages and programming has been critical for building trust within the community and encouraging participation in programs that have resulted