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Analyzing Patterns of Community Interest at a Legacy Mining Waste Site to Assess and Inform Environmental Health Literacy Efforts

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Abstract

Understanding a community's concerns and informational needs is crucial to conducting and improving environmental health research and literacy initiatives. We hypothesized that analysis of community inquiries over time at a legacy mining site would be an effective method for assessing environmental health literacy efforts and determining whether community concerns were thoroughly addressed. Through a qualitative analysis, we determined community concerns at the time of being listed as a Superfund site. We analyzed how community concerns changed from this starting point over the subsequent years, and whether: 1) communication materials produced by the USEPA and other media were aligned with community concerns; and 2) these changes demonstrated a progression of the community's understanding resulting from community involvement and engaged research efforts. We observed that when the Superfund site was first listed, community members were most concerned with USEPA management, remediation, site-specific issues, health effects, and environmental monitoring efforts related to air/dust and water. Over the next five years, community inquiries shifted significantly to include exposure assessment and reduction methods and issues unrelated to the site, particularly the local public water supply and home water treatment systems. Such documentation of community inquiries over time at contaminated sites is a novel method to assess environmental health literacy efforts and determine whether community concerns were thoroughly addressed.

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Conflict of Interest

None to report.

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1.0 Introduction

Understanding a community's perspective and informational needs is crucial to conducting and improving environmental health research and literacy initiatives, especially in the context of contaminated sites. One in four Americans lives within 3 miles of a hazardous waste site (U.S. GAO, 2013), of which there are approximately 235,000–355,000 in the U.S. (USEPA, 2004). Of these, 1,323 are designated as National Priorities List (NPL) or "Superfund" sites, which refers to an uncontrolled or abandoned hazardous waste site designated for remediation under the Comprehensive Environmental Response, Compensation and Liability Act of 1980. The U.S. Environmental Protection Agency (USEPA) manages remediation of these sites, and the projected life cycle of a remediation program is on the order of decades (National Research Council, 2012). Thirty-three nonfederal mining sites are on the NPL; it is estimated that there are an additional 161,000 abandoned hardrock mine sites in the U.S., and a minimum of 33,000 sites have contaminated water and arsenic-contaminated tailings piles (U.S. GAO, 2013). Mining and smelting activities are the primary source of metals entering the environment (Lee et al., 2005), and the fine-grained byproduct of the ore processing (crushing, milling, and leaching), referred to as mine tailings, is the largest global industrial waste stream (Lottermoser, 2011; Hudson-Edwards et al., 2011). Mine tailings, particularly from legacy mining sites, pose a threat to public health because of their increased vulnerability to particle dispersion from wind and water erosion (Mendez and Maier, 2008), which can then contaminate nearby soils, waterways and air.

1.1. Theoretical and Analytical Perspectives

In this section, we cover the following theoretical areas to set the stage for the research described herein: risk communication, environmental justice, environmental health literacy, and community-based participatory research. In general, once a site is placed on the NPL, the appropriate regional USEPA office oversees a variety of assessments and cleanup activities. In parallel, USEPA Community Involvement Coordinators oversee a Community Involvement Program (CIP) designed to identify major concerns of community members and stakeholders (local, state and federal regulatory agencies, potentially responsible parties) and identify how to best disseminate information about the site cleanup status to these groups (USEPA CIP, 2009).

However, studies have shown that traditional USEPA outreach efforts typically follow a one-way communication model that aims to inform, change behavior, and assure populations that the determined risk is acceptable and that cleanup is underway (Chess and Purchell, 1999; Cox, 2013; NRC, 1996). This communication strategy has a low rate of success, primarily because communities historically do not trust regulatory officials and scientists (White et al., 2014; Senier et al., 2008; Gaetke et al., 2008). Additionally, such outreach models generally

do not involve the community in a meaningful way, as they fail to 1) modify participation formats to community characteristics and needs or 2) provide multiple formats for public participation. Feedback on efforts to determine success of outreach models is seldom collected (Chess and Purchell, 1999). These issues are not unique to USEPA Superfund sites; community members neighboring contaminated sites managed by the U.S. Department of Energy have highlighted the federal agency's inability to help set site-related priorities and their lack of influence in overall decision-making (Hoover, 2013; Bradbury et al., 2003). Furthermore, the literature on environmental justice has demonstrated time and time again that minority and low-income communities bear disproportionate impacts of environmental pollution. Socioeconomic variables, along with others such as linguistic isolation and measures of political engagement, are factors in the spatial distribution of environmental hazards (e.g. Agyeman et al., 2010; Callahan et al., 2012; Morello-Frosch and Lopez, 2006; Pastor et al., 2006) and these variables further exacerbate community engagement and education efforts at contaminated sites.

Beyond community involvement, efforts are needed to improve environmental health literacy (EHL). As defined by the Society For Public Health Education (2007), EHL is being able to "integrate concepts from both environmental literacy and health literacy to develop the wide range of skills and competencies that people need in order to seek out, comprehend, evaluate, and use environmental health information to make informed choices, reduce health risks, improve quality of life and protect the environment." However, health literacy efforts are traditionally assessed through literacy and numeracy surveys (e.g. Zorn et al., 2004; Berkman et al., 2011) and overlook an individual's capacity to analyze and apply existing data and participate in scientific research. To measure these outcomes, which may be better indicators of a community's EHL, a new way of assessing EHL is needed. Informal science education (ISE), or science learning opportunities that people experience across their lifespan outside of school (Bonney et al., 2009; NRC, 2009), are important to consider for communities impacted by hazardous waste. EHL efforts are of little value 1) if they do not help communities make informed choices to reduce hazardous exposures and 2) if these efforts are not partnered with local knowledge (White et al., 2014; Corburn, 2002). It has been established that individuals living near contamination are motivated to engage in environmental health research and work with outside partners, such as public health officials and researchers (e.g. Brown, 1992). However, what is missing from the traditional community involvement and EHL programs are efforts by government and academic stakeholders to build productive partnerships, and cultivate ISE learning opportunities via public participation in environmental research and risk assessment projects (Ramirez-Andreotta et al., 2014a). Concerned community members often learn about health related topics via informal settings and engage in free choice learning (i.e. Dickenson et al 2004). Importantly, such learning is personal, contextualized, correlated with individual interests and motivation (Falk et al,, 2007; NRC, 2009) and takes time (Rennie and Johnston, 2004). Thus, it is critical to document community concerns over time to better understand how community EHL has changed.

Lastly, community-academic partnerships have been changing the way research is conducted and have produced research products that are much more applicable to community members than expert-only led investigations (Brown et al., 2012; Silka and Renault-Caragianes,

2007). These partnerships have the capacity to cultivate ISE learning opportunities via public participation in environmental research projects and risk assessment. Federal granting programs such as the National Institutes of Environmental Health Sciences (NIEHS) Superfund Research Program (SRP), designed to support remediation and biomedical investigations at NPL sites, require both a Research Translation Core (RTC) and Community Engagement Core (CEC). The SRP RTC and CEC are tasked with serving as knowledge brokers for the multidirectional flow of information between the decision makers and scientific experts throughout the regulatory environment (Pennell et al., 2013; Senier et al., 2008). These cores can serve as the conduit between all parties affected by a contaminated site and assist in environmental research translation initiatives that are rooted in public participation approaches (Ramirez-Andreotta et al., 2014a).

Within the above frameworks, we evaluate EHL in a legacy mining community by assessing: 1) what information community members initially desired; 2) whether those concerns changed over time; 3) whether USEPA and other media were aligned with community concerns; and 4) whether there was a progression of understanding (from knowledge to application) resulting from community involvement and engaged research efforts. We hypothesized that such documentation of community inquiries at a contaminated site would be an effective rubric by which to assess EHL efforts and determine if community concerns were addressed, ultimately leading to productive EHL and community engagement efforts.

2.0 Materials and Methods

2.1. Site Description

Dewey-Humboldt is a rural community of 3,894 people (U.S. Census Bureau, 2010.) about 140 km north of Phoenix in central Arizona, USA and is home to the Iron King Mine and Humboldt Smelter Superfund site (IKMHSS). The Iron King Mine operated periodically from 1904 until 1969, producing gold, silver, copper, lead and zinc. The Humboldt Smelter operated from the late 1800s until the early 1960s, when all mining and smelting ceased (USEPA, 2009). The average concentration of arsenic in the Iron King Mine tailings pile (0–0.61 m below ground surface) is 3,710 mg kg^{-1} (EA Engineering, Science, and Technology, Inc., 2010). An estimated four million cubic meters of mine tailings, containing arsenic and other contaminants, are subject to wind and water erosion into adjacent locations and pose an environmental health risk to neighboring communities and ecosystems (Csavina et al., 2012; Ramirez-Andreotta et al., 2013b; Root et al., 2015). It was placed on the USEPA NPL in 2008 (USEPA, 2009).

2.2. University Involvement

The University of Arizona Superfund Research Program (UA SRP) initiated a dialogue with the USEPA regarding the IKMHSS in June 2007 and engaged community members neighboring the Superfund Site starting in August 2008. As a result, community concerns and USEPA research needs drove new UA SRP research and informed the development of informational materials for distribution in the community. The UA SRP is a multi-project program, including five projects focused on the legacy of mining-associated wastes in Dewey-Humboldt, two of which were developed in direct response to community concerns:

Gardenroots and the Metals Exposure Study in Homes (MESH). Gardenroots, the co-created citizen science program, was designed in response to home gardening concerns over possible contamination and potential risks associated with community members' water, soils and vegetables samples (Ramirez-Andreotta et al., 2013a; Ramirez-Andreotta et al., 2013b). The MESH project was developed in response to community concerns of exposure to mine waste contaminants, and assessed metal(loid) pathways and levels of exposure in local residents, specifically in the vulnerable population of children aged 1–11 years.

2.3. Data Analysis

Changes in community concerns over time were used to measure the success and adequacy of EHL efforts. We hypothesized that changing concerns and inquiries would demonstrate the progression of knowledge resulting from community involvement and engaged research efforts. In order to determine what information community members living near the site desired, we analyzed public community comments and inquiries, as well as community information sources beginning the year the site was placed on the NPL and one year after (baseline), and then in the four years that followed. We conducted an instrumental case study, defined as studying a bounded system over time, through detailed, in-depth data collection involving multiple sources of information (Creswell, 2007; Yin, 2003). Patterns of community concerns and interests were evaluated from a variety of public sources (described in detail below) from August 2008 through December 2013. Questions and comments from the sources were coded based on one theme per question or observation and could not be coded more than once. The sources were observations documented during publically advertised USEPA or UA SRP meetings and engagement activities. In general, USEPA community meetings consisted of USEPA and other site-related personnel presenting sampling and study findings, followed by questions from the audience.

To create a baseline of community concerns in the immediate time period after the site was named to the NPL in 2008, we analyzed what information community members initially desired from a total of 112 inquiries and comments from:

1. The first USEPA Community Meeting after being placed on NPL in August 2008, where 46 community members attended, and 24 inquiries were recorded and analyzed.
2. Informal interviews completed as part of the USEPA Community Involvement Program (CIP). In 2009, the USEPA and Arizona Department of Environmental Quality developed the CIP, based in part on 19 interviews with local residents. The CIP interview questions analyzed in this study are: 1) What are your concerns about the site and its cleanup?; 2) What is your biggest concern and do you know if anything has been done to address this concern?; and 3) Is there anything else you would like to share about the site? (USEPA CIP, 2009). Eighty seven responses were analyzed.

To determine whether community concerns changed over time in comparison to the baseline, we collected and analyzed 128 inquiries and comments from:

1. USEPA Superfund community meetings held in August 2011, April 2012, April 2013 and December 2013. Between 50–60 community members attended each meeting.
2. UA SRP research meetings and community engagement activities (Gardenroots citizen science research project training sessions held in March 2011, where a total of 41 individuals attended both trainings, and a community health presentation held in June 2011 with nine community members present).
3. Dewey-Humboldt Environmental Issues Advisory Committee held in January 2012. At this meeting, five committee members were present.

To determine if information disseminated by USEPA and through local media outlets and was aligned with community inquiries, we analyzed materials produced from 2008 to 2013:

1. Articles from local print media: the Prescott Daily Courier, the Prescott Valley Tribune, and Big Bug News, which represent pay-for newspaper coverage of regional issues in and around Dewey-Humboldt. Articles were coded by major content topics, with from 1 to 5 different themes assigned to one article.
2. Articles from the Dewey-Humboldt Newsletter, which is mailed free of charge to all Town residents and is freely available online. It is generated solely from community member-submitted content and was distributed quarterly until 2010, after which it was distributed monthly. Articles were coded by major content topics, with 1 to 5 different themes assigned to each article.
3. Minutes from Dewey-Humboldt Town Council Meetings, which include both official town business and dialogue among citizens and Town Council members about various issues affecting the Town. These minutes include regular meetings and study and special sessions. The meetings are open to the public and recorded Meeting Minutes are freely available online. Meeting minutes were coded based on general discussion topics; each discussion topic was coded to one theme.
4. USEPA Superfund site-specific Factsheets, which included all public information materials available from the USEPA website at time of manuscript preparation (October 2014). These factsheets were mailed to all community residents to inform them of progress and upcoming work at the site and offered opportunities to learn more about the site. Factsheets were coded as newspaper articles.

We conducted a content analysis of the sources. First, members of the research team reviewed materials and developed a preliminary list of topic codes (EPA management, remediation, environmental monitoring, health, communication, origins of site contamination, and water) (Lofland et al., 2005). Research team members independently assigned these codes to community inquiries and comments recorded at USEPA community meetings and UA SRP meetings and community engagement activities. Next, we informally

compared coding results to assess interrelated reliability. Differences between the team members' coding results were discussed and reconciled to prevent inappropriate coding. A total of 18 topics of interest were identified (Table 1). The final codebook includes the code name, brief definition, and examples of the text (available upon request) (Scammell et al., 2009; MacQueen et al., 1998). To identify potentially pertinent text in media source materials, we searched each media item with the following keywords: *Superfund, EPA, water, arsenic, metals, soils, contamination, risk, health* and *mine*. Relevant findings were then coded accordingly. Lastly, to determine whether there was a statistically significant association between the frequency of concerns (N values) at baseline (2008 and 2009) and those from 2011–2013, we conducted a chi-square test for each topic using the following formula:

$$\chi^2 = \sum_{i-1}^{r} \sum_{j-1}^{c} \frac{(A_{ij} - E_{ij})^2}{E_{ij}}$$

In this equation, A_{ij} = actual frequency in the i-th row and j-th column, E_{ij} is the expected frequency in the i-th row and j-th column, r = number of rows and c = number of columns. All statistical analyses were performed using Microsoft Excel 2011 (Microsoft Corporation, Redmond, WA). . We used an alpha level >0.05 to qualify statistical significance.

This study was exempt from University of Arizona Institutional Review Board approval since the data was collected at public meetings, and all documents are publicly available

3.0 Results

3.1. Topics and Themes

A total of 239 community inquiries (at baseline and between 2011–2013) were analyzed, and 18 topics were identified. These topics were grouped into eight themes (Figure 1). For clarification, EPA Process, Management, Updates refers to Superfund assessments, personnel, and project management; Communication, to site-related meeting announcements; Site-Specific-Mine, to the Iron King Mine and Humboldt Smelter property itself and Remediation, to site and affected areas clean up, as well as potential reuse of the site.

3.2. Baseline Community Inquiries

As noted in section 2.0, we use the first community concerns raised when the site was listed as an NPL in 2008 and the following year as a baseline. We then look at concerns over time at various community meetings as described below in section 3.3. As Figure 1 demonstrates, the top six topics listed in order of decreasing frequency were: EPA Process, Management, Updates (N=18); Remediation (N=12); Site-Specific-Mine (N=11); Health (N=11); and (tied). Environmental Monitoring-air/dust (N=10) and Environmental Monitoring-water (N=10).

3.3. Comparing Baseline Inquiries to Those from 2011 through 2013

To determine whether community concerns changed over time, we compared concerns from 2011 through 2013 to baseline concerns. We analyzed 128 citizen comments collected from 2011 through 2013 and categorized them by the aforementioned topics and themes (Figure 1). The top five topics listed in order of decreasing frequency from 2011–2013 were: Exposure/Risk Reduction (N=18), EPA Process, Management, Updates (N=13), Site-Specific-Mine (N=12), and (tied) Water-treatment systems (N=10), Remediation (N=10), and Health (N=10).

As shown in Figure 1, when comparing 2011–2013 inquiries to baseline, there was a statistically significant increase ($p<0.05$) in inquiries related to exposure/risk assessment and exposure/risk reduction methods, the public water supply, and home water treatment systems, and these increases were seen in years 2012 and 2013, 2013, and 2011, respectively (Table 1). There was a noticeable but statistically insignificant reduction in inquiries related to Environmental Monitoring-vegetables. EPA Process, Management and Updates and Environmental Monitoring-air/dust decreased in 2012 and 2013, but these reductions were not statistically significant. Inquiries related to Environmental Monitoring-soil, Property Values, Site Specific-Mine, and remediation remained consistent from when the site was placed on the NPL in 2008 to 2013.

3.4. Community Public Media Sources

To determine if information disseminated by USEPA and through local media outlets was related to community concerns, we compared topics identified in informational sources to those identified as community concerns (Figure 2). We analyzed sources generated between 2008 through 2013: local news articles (83); the Dewey-Humboldt Newsletter (51); Dewey-Humboldt Town Council Meeting Minutes (224); and USEPA Factsheets (14). The top five topics covered by these informational sources and listed in order of decreasing frequency were: EPA Process, Management, and Updates (N=69), Communication (N=32), Research Studies-Environmental Health (N=28), Remediation (N=28), Environmental Monitoring-General (N=23), and Environmental Monitoring-Soils (N=23). Overall, the EPA Factsheets provided the most information regarding EPA Management, Process, and Updates (in all 14 factsheets), Environmental Monitoring-soils (N=11), and communication (N=9) about upcoming meetings, although the Factsheets did not provide information about water unrelated to the site. The town newsletters provided the most information regarding EPA Management, Process, and Updates (N=12) and highlighted the UA SRP environmental health research studies (topic under theme group of Health) (N=12), followed by Environmental Monitoring-Vegetables (N=6). The regional press covered the most information regarding EPA Management, Process, and Updates (N=23), Environmental Monitoring-General (N=15), and Exposure/Risk assessment (N=16). Town Council meeting discussions that related to the Superfund site were most frequently concerning EPA Management, Process, and Updates (N=19), Remediation (N=14), and Site-Specific-Mine (N=8).

4.0 Discussion

By evaluating community inquiries over time, we assessed what community members were most concerned about at a legacy mining and smelting Superfund site, whether these concerns changed, and whether these concerns were adequately addressed through accessible sources of information. In addition, we hypothesized that the changes in concern and inquiry over time would demonstrate a progression of the community's understanding (going from knowledge acquisition to application) resulting from community involvement and engaged research efforts. A key finding of this study that can guide other studies with communities living near contamination, was that a cross-sectional analysis at one point in time is inadequate to describe the social–ecological developments within a community. By having a comparison, we showed how community concerns changed over time as a result of USEPA and research activities. We have demonstrated that when the Superfund site was first listed, community members were initially most concerned with USEPA management, remediation, specific issues related to the mining site, health effects, and environmental monitoring efforts related to air/dust and water. Within five years, community inquiries shifted to concerns related to exposure assessment and reduction methods, the public water supply, and home water treatment systems. Concerns related to environmental monitoring of soils, property values, and site-specific issues related to the mining site remained consistent throughout. Over time, as community involvement increased and engaged research efforts took place, we noticed a statistically significant shift from inquiries about environmental monitoring and origins of contamination (site specific), to concerns about exposure pathways and reduction methodologies. These changes demonstrate broader community recognition of the fundamentals of environmental health research (i.e. from understanding the source to potential exposure pathways and exposure mitigation).

We recognize that there are operationally defined assumptions and limitations associated with this study including the different data formats (i.e. the USEPA interview data and inquiries collected at community meetings are not totally comparable). Only a small amount of community inquiry data was collected in 2012 (there were only two meetings where observations were recorded) and no data was collected in 2010. To the best of our knowledge, there was only one USEPA community meeting in which a UA SRP researcher presented preliminary findings, but no observations were recorded. Although the majority of EPA meetings had a minimum of 50 participants, there was a potential for a number of the inquiries to have come from a small number of active/engaged community members; there were over 200 inquiries recorded, but we do not know who voiced each concern.

The strength of this study is that it has given us insight into what people want to know and how community concerns change over time at a community level. When recognizing community members as experts in their own right (Corburn, 2005), such information can be used to inform EHL practices and guide communication and research efforts at additional legacy mining sites.

4.1. Implications for Mining Communities

4.1.1. Inquiries that Decreased over Time—Questions related to EPA Process, Management, Updates were most frequently asked at the time the site was listed (baseline)

and were the most consistently asked of any topic from 2008–2013, but showed a decrease in frequency between 2011–2013 relative to baseline. This decrease in inquiries may be due to information communicated from the USEPA factsheets generated during this time. In the majority of factsheets, the iterative steps of the Superfund cleanup process were explained and included graphics. Updates on the cleanup process were also described by the USEPA at community meetings and in Town Council meetings. The reason that questions related to EPA Process, Management, Updates were not completely mitigated could stem from three major observations we witnessed throughout the Superfund cleanup process thus far. First, in 2012, USEPA announced that the 2010 Remedial Investigation (RI) Report was inadequate and needed to be recreated, setting the entire Superfund cleanup process behind by a minimum of four years, and led to questions such as, “How did you know the [first] RI was inadequate?” Second, there have been multiple personnel changes at the local, state, and federal level since the site listing. The community took note of this and at a meeting several members asked whether USEPA staffing “will stay consistent.” Third, specific values for measured soil and water concentrations were rarely reported by USEPA in public forums. Community questions revealed that community members wanted this “raw data,” rather than generalizations, e.g., “[we] always see the same thing [at these presentations] and no [actual] results.” This demonstrates the value of community involvement to highlight shortcomings and areas of potential improvement in management (USEPA) reporting and communication.

Inquiries related to Environmental Monitoring-vegetables demonstrated a noticeable but statistically insignificant decrease over time. Our analysis demonstrates that the observed reduction is likely associated with the co-created citizen science program, Gardenroots (Ramirez-Andreotta et al., 2013a; 2013b; 2014b). The majority of Gardenroots activities occurred from 2010 through 2012, and involved the public in the scientific process and provided data directly to the community.

4.1.2. Inquiries that Increased over Time—Inquiries relating to the public water supply, home treatment systems to reduce arsenic, exposure/risk assessment and exposure/risk reduction methodologies were not an initial concern, but a significant increase was observed in 2011–2013 (Figure 1). This shift may be attributed to two factors. First, in January 2012 and January 2013, UA SRP analyses of drinking water in local homes demonstrated that arsenic was above the USEPA drinking water standard (arsenic maximum contaminant level (MCL)=10 ppb) (Ramirez-Andreotta et al., 2013b; Loh et al., 2013). The community used this information to alert the public water supplier and AZ Dept. of Environmental Quality (ADEQ) to the problem and ADEQ issued a notice of violation to the water utility for exceeding the arsenic MCL as well as other regulated contaminants (Ramirez-Andreotta et al., 2014b). The public water supplier reported four instances of arsenic exceedances to the community in the Dewey-Humboldt town Newsletter. At a meeting in 2013, community members asked, “Why is the public being told that the water is “safe” when it’s not?” One woman remarked, “I drank copious amounts of water while pregnant, is the effect to the fetus more serious than a grown child? [She began crying] I feel responsible. My husband bought the home when we were in California and we thought, ‘well water that is so nice and fresh.’ We did not know or were [not] told to test our private well. Why, why doesn’t anyone say anything?” The public water supplier’s exceedance of

the arsenic MCL, combined with UA SRP research results, are the most likely reasons for an increase in inquiries related to the public water system.

Arsenic treatment options also demonstrated a marked increase. Community awareness of elevated arsenic levels from the public water system and private wells likely contributed to an increased interest in home water treatment systems. In 2013, a community member asked: “What if people can’t afford the treatment systems, or other options to help clean up their water?” As demonstrated above, community involvement ensured our research endeavors were applicable and relevant and allowed us to produce better educational materials. In response to water-related concerns, the UA SRP delivered presentations regarding water quality, testing and treatment systems in January 2012, December 2012, and December 2013. Additionally, with input from the Agency for Toxic Substances and Disease Registry (ATSDR) Region 9, AZ Dept. of Health Services, USEPA Region 9, and ADEQ, the UA SRP prepared a handout entitled, “Arsenic in drinking water: what you need to know.” The handout details testing and treatment options for arsenic in drinking water. In a similar effort, the UA SRP provided content and editorial advice on a document developed and published by ATSDR and Arizona Department of Health Services (ADHS), “How to Reduce Your Exposure to Arsenic and Lead in Dewey-Humboldt, Arizona.” Both have been made available to the community in print copy at community meetings and the local library, sent to MESH participants, and published online. More recently, Artiola and Wilkinson (2015) completed an Arizona Cooperative Extension publication entitled: “How to Lower the Levels of Arsenic in Well Water: What Choices Do Arizona Consumers Have?” which provides specific details regarding appropriate home water treatment options.

Community-identified issues may provide opportunities where a nongovernmental agency like a university can step in, build a community-academic partnership, conduct community-engaged research, and generate appropriate educational materials. It is likely that the elevated arsenic in Dewey-Humboldt drinking water is not directly related to the Superfund site, but an indirect consequence of living in a high-mineral region. The geology of the area predisposes groundwater sources to arsenic contamination, and the regulatory agencies and UA SRP have recognized the need to clarify that the water treatment issue is likely not related to the Superfund cleanup. An interesting outcome is that a salient environmental health education campaign has emerged around informing residents, particularly well water users, about regular testing of their water supply. This is not a Superfund site-related activity per se, but has arisen because the public was given in-home water quality results. Increases in water-related concerns over time illustrate how an issue unrelated to the site and outside of USEPA jurisdiction requires other groups to step in to deliver information the community desires. Further, this is an important issue that would not be impacted by the Superfund cleanup, illustrating that when engaging the community, one might observe other important public environmental health needs that are not a direct consequence of the site. Even though they are not site-related, ignoring such public health issues would be a disservice to the community.

4.1.3. Persistent Inquiries over Time Due to Lack of Standards and Passing of Responsibility—Community concerns and inquiries related to environmental monitoring of soils, property values, and site-specific issues related to the mining site varied little over

time. This persistence may be due to the Remediation Investigation reanalysis, which, among many other items, will redefine to what soil arsenic concentration the USEPA will clean up residential properties. Anthropogenic sources combined with naturally occurring arsenic near mining sites can complicate cleanup and add another dimension of complexity when attempting to communicate cleanup actions. Background arsenic concentrations in soils do not generally exceed 40 mg kg^{-1}, but soil contaminated by mining, industrial or agricultural activity can reach several thousands of mg kg^{-1} in the surface horizons (Smith et al., 1998). There are currently no federal regulatory standards for arsenic in residential soils in the U.S., although states have set varying cleanup standards. These remediation standards can be problematic because they can be lower than the natural background levels in soil; for example, AZ has a recommended residential limit of 10 mg kg^{-1} (Arizona Administrative Code). Yavapai County, the area in which the Dewey-Humboldt community is located, is in a mineral rich zone and subsequently arsenic endemic area, and metals in soils are higher than in most other areas of the country (Smith et al., 2013). Community inquiries reflect the challenges and complexities associated with soil cleanup; for example, community members asked: “How far away do you think a background sampling needs to be to considered a reliable source for background?” and “In regards to arsenic, will you need to check the entire state of Arizona?”

In addition, bioavailability of arsenic in soil (i.e. the percentage of arsenic that remains in the body after it is ingested) further complicates the discussion. Bioaccessible arsenic in soils may range from 6–95% using various *in vitro* models, although in most cases it is 59% or below (Oomen et al., 2002). Currently, the USEPA tentative low risk range for arsenic levels in soil at the IKMHSS is 145 mg kg^{-1} (assuming 20% bioavailability) to 61 mg kg^{-1} (assuming 60% bioavailability) (USEPA Fact Sheet, November 2013). Considering the extent of contamination and bioaccessibilty, the USEPA is working on delineating an Area of Potential Site Impact, which would provide an invisible line defining the extent of contamination from the Superfund site versus naturally occurring arsenic. This has implications for local residential cleanup, and has raised community concerns about what levels are safe. Our analysis demonstrates that cleanup decisions will create concern in the community and perhaps raise ethical questions.

Superfund site effects on property values were another ongoing concern of the community. For example, after the Gardenroots and MESH studies, participants asked what impact the study results would have on their home values. The following statements/questions demonstrate a degree of awareness and concern about the possible economic impacts, in particular home prices, “How will property values be affected [by the IKMHSS]? My home now carries a certificate of contamination…” and “What do you say when people are buying property [in the area]?” The USEPA acknowledges the difficulties of evaluating changes in property values near listed Superfund sites. While indicating that much remains to be done in the area of hedonic analysis (regression of property values), overall it is difficult to quantify the economic impact of Superfund sites in this and other communities due to: site size, degree of attention given by news media and public interest groups, public perceptions, and site cleanup methods (USEPA, 2011). Whether it can be quantified or not, it is clear this is a persistent community concern which requires resources beyond what USEPA and many

other government agencies can offer, presenting an opportunity for academic or non-profit groups to provide resources to the community.

4.2. Recommendations

Based on the data and observations reported here, we offer recommendations to better assess and implement EHL efforts to empower communities impacted by hazardous waste with knowledge.

4.2.1. Improve Data Collection of Community Concerns—Documenting concerns in communities affected by legacy mining Superfund sites over time can help better address community concerns and illuminate changes in EHL. We have demonstrated that documenting community inquiries during open forums at community meetings is a successful way to monitor community concerns and interests that may not be recorded by traditional feedback methods. Additionally, traditional feedback methods typically provide a snapshot of knowledge and awareness at a single point in time and do not capture the nuances and evolution of concerns of those living near a hazardous waste site. It has also been recommended that efforts need to be invested in further defining and measuring a wider set of parameters that would more adequately and successfully reflect community health literacy (Berkman et al., 2011). We were able to document the succession of questions over time and changes on a community level. For example, there was an increase in the number of questions related to risk assessment and risk reduction methods (Table 1), and these increases are likely due in part to the number of individuals participating in community-engaged research projects and an increase in information available to the community (USEPA factsheets, UA SRP information materials). Community concerns have driven UA SRP research (described above in section 2.2), as well as advised the development of informational materials for distribution in the community (described in section 4.1.2). In both Gardenroots and MESH, participants received individual and aggregate results, as well as guidelines for best practices to limit exposure. Research coordinators were actively involved in discussing results with participants via group meetings and personal calls, which provided an opportunity to have a bi-directional discussion about the results. These studies also engaged the community by: involving residents in the collection of environmental samples, the dissemination of conclusions and translation of results into action (Gardenroots; Ramirez-Andreotta et al., 2014); and by hiring local residents as field staff who were responsible for recruitment and sample collection (Loh et al., 2013).

4.2.2. Addressing the Broader Public Health Spectrum at Superfund Sites—Based upon our observations reported here, it is crucial to address a wide spectrum of issues when working with communities neighboring contamination. Dewey-Humboldt, AZ residents expressed concern and showed anguish when speaking about possible negative impacts on property values. Others openly expressed anger because they were unaware of the Superfund site when they moved to the town, and many were frustrated about the presence of arsenic in their drinking water. Strategies that include and address all aspects of public health at a Superfund sites are needed to assist individuals and communities. These strategies should include programs (possibly managed by local/state health agencies) to deal with the stresses associated with living near a Superfund Site in an arsenic endemic area as

well as tools to analyze how the site listing will impact their property values and economic standing. For example, a rigorous hedonic analysis of Dewey-Humboldt since the listing of the Superfund site may help residents to cope with its present and future potential economic impact (USEPA, 2009). Communities near future Superfund sites may also use these data and other hedonic analyses to proactively implement coping strategies that minimize economic disruptions during remediation of a Superfund site.

4.2.3. Report Data to the Community—It has been observed that people can understand environmental and biomonitoring data, and they greatly appreciate and benefit from learning the actual results and collection methodologies (Brody et al., 2007; Adams et al., 2011; Ramirez-Andreotta et al., 2014b). Based on our analysis, very few USEPA informational materials reported actual data, with exception of the November 2013 fact sheet mailing, which provided site-specific soil arsenic concentrations associated with varying bioavailability percentages. As mentioned above in section 4.2.1, we strongly recommend that community members be given specific information, including measured data values along with comparative regulatory and bioavailability values, field methodologies, and parameters used in assessing exposures and risk. It has been observed that participants' experience of trust or distrust in agencies during environmental health studies and their sense of trust and relative power influence how they assess the findings of environmental health studies (Scammel et al., 2009). In October of 2012, as the MESH study was beginning, the UA SRP convened a community advisory board (CAB), outside of regulatory agency mechanisms for such groups, which provides a platform for bidirectional community-academic interactions. In general, communities neighboring hazardous waste sites lack trust in government agencies (Senier et al., 2008); therefore, the establishment of the CAB by a "neutral" group provided a venue where community members could openly discuss their concerns outside of government-convened public meetings. Establishing a CAB (with or without government affiliation or funding) is recommended and a wise use of limited resources.

4.2.4. Community Participation in Environmental Projects—In addition to a high volume of inquiries related to health, many community inquiries were related to environmental monitoring, and community members wanted to know why and where monitoring efforts were taking place. This was an exciting observation and provides a rationale for including a community in environmental monitoring efforts throughout their residential area and surrounding environment. Community members are generating their own hypotheses and considering what types of data to collect. For example, a subset of community members' questions were: "When it rains, several washes near the mine can carry tailings downstream…has there been any impact to water wells located downstream?" and "Where are the wells? When will you sample and how many?", "Are you [measuring] arsenic speciation in water?", "What will you do with the [mine] runoff?" An often-overlooked opportunity in community involvement efforts is public participation in environmental research and risk assessment projects (Ramirez-Andreotta et al., 2014a). EHL can be increased in communities near contaminated sites with a citizen science approach (Bonney et al., 2009), a cultural model of risk communication (Cox, 2013; NRC, 1996), and community-based participatory research (Ramirez-Andreotta et al., 2014b). Recently, at a

USEPA Workshop, it was stated that citizens can, in general, contribute to environmental monitoring projects and that the samples collected would not replace USEPA's efforts, but would provide valuable supplemental data (Enck, 2014). It has been established that trained nonscientists can collect viable samples (e.g. Bonney et al., 2014), and observing the encouragement of citizen science projects from a regulatory agency is exciting to witness. Furthermore, public participation in scientific investigations will produce more data and can identify new environmental health issues.

5.0 Conclusions

Our study illustrates that a cross-sectional analysis at multiple points in time can describe the social–ecological developments within a community. As community involvement increased and engaged research efforts took place, baseline inquiries about environmental monitoring and origins of contamination (site specific) gave way to concerns about exposure pathways and reduction methodologies. These changes demonstrate community recognition of the fundamentals of environmental health research and this new information can inform managers, administrators and researchers on how to continue to respond to and increase a community's environmental health literacy. In addition to "checking in" with communities at multiple points in time, there should also be a way for community members to contribute, and assist in, the Superfund process, specifically the Remedial Investigation, which currently has no community participation/engagement component and may result in community disengagement and limited environmental education. Involving the affected community via community-engaged research and participation in environmental projects during the USEPA's Superfund management is critical in order to address environmental health literacy. The benefits of an environmentally health literate community can lead to improvements in one's environmental awareness, sense of control, and ability to make informed decisions and take measure to mitigate potential exposures.

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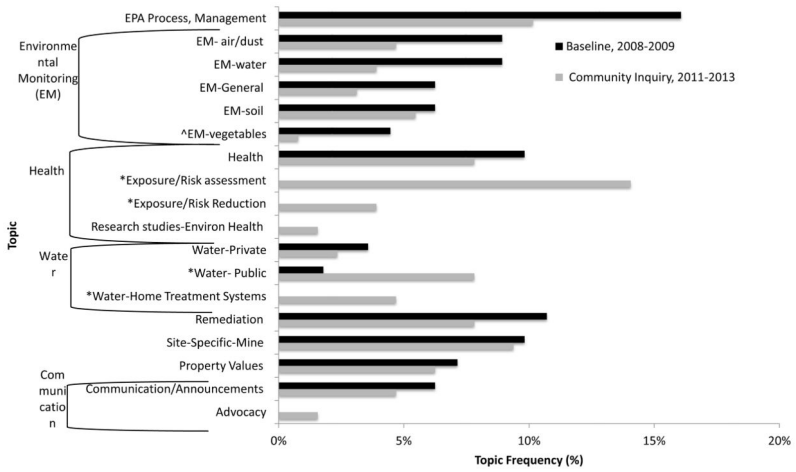

Figure 1.

Frequency of community inquiries related to the 18 topics at baseline (established during 2008 and 2009) and in the subsequent years, 2011 through 2013. Brackets show topics that fall under major themes. The * indicates statistical significance ($p \leq 0.05$) and the ^ indicates a noticeable change, but statistically insignificant.

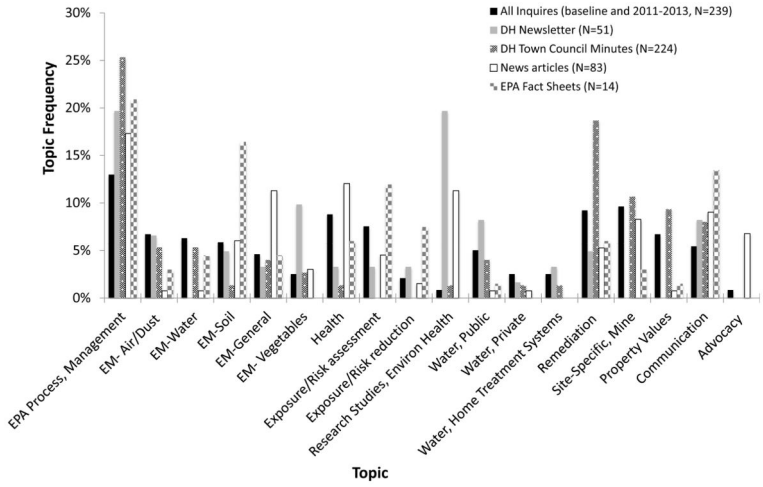

Figure 2.

A comparison of all community inquiries beginning in August 2008 through 2013 (baseline and subsequent inquiries) to various information sources likely available to a community member living in the area. Topic frequency is illustrated by the percentage a given informational source discussed a topic related to the Superfund site

Table 1

Percentage (frequency) of community inquires by topic in 2008–2009 (baseline), 2011, 2012, and 2013. Color gradient indicates the frequency of topic by year from highest (black) to lowest (white).

Topic	2008–2009 (Baseline)	2011	2012	2013
EPA Process, Management, and Updates	16% (n=18)	11% (7)	0%	11% (6)
Environmental Monitoring, General	6% (7)	0%	27% (3)	2% (1)
Environmental Monitoring, Air/Dust	9% (10)	10% (6)	0%	0%
Environmental Monitoring, Water	9% (10)	2% (1)	9% (1)	5% (3)
Environmental Monitoring, Soil	6% (7)	7% (4)	9% (1)	4% (2)
Environmental Monitoring, Vegetables	5% (5)	2% (1)	0%	0%
Health	10% (11)	11% (7)	18% (2)	2% (1)
Exposure/Risk Assessment	0%	15% (9)	0%	16% (9)
Exposure/Risk Reduction	0%	3% (2)	18% (2)	2% (1)
Research studies, Environ Health	0%	2% (1)	0%	2% (1)
Water, Private	4% (4)	0%	9% (1)	4% (2)
Water, Public	2% (2)	2% (1)	0%	16% (9)
Water, Home Treatment Systems	0%	8% (5)	0%	2% (1)
Remediation	11% (12)	10% (6)	9% (1)	5% (3)
Site-Specific, Mine	10% (11)	8% (5)	0%	13% (7)
Property Values	7% (8)	5% (3)	0%	9% (5)
Communication/Announcements	6% (7)	2% (1)	0%	9% (5)
Advocacy	0%	3% (2)	0%	0%
Total Number of Inquiries by Year	**112**	**61**	**11**	**56**