

RESEARCH ARTICLE

Leveraging integrative research for inclusive innovation: urine diversion and re-use in agriculture

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This report describes the evolution of a qualitative research design used in a study that integrated academic and non-academic expertise and involved multiple stakeholders concerned with the diversion of human urine from the waste stream for its re-use in agriculture. The study took place in two regions of the U.S., New England and the Upper Midwest (most specifically Vermont and Michigan) and suggests the importance of ethnographic perspectives in a participatory action research framework going forward. This manuscript presents a novel mix of researchers, from a grassroots organization to R1 University teams, and explores the perspectives of a wide range of research participants with whom we conferred to understand whether and how fertilizers made from nutrients recovered from diverted urine might be accepted, adapted, and scaled in agricultural use. Our manuscript thus articulates new territory for such interpretive social science work (focus groups, interviews and participant observations) neither within basic ethnographic research, nor within the kind of “rapid ethnography” widely used in business, engineering and international development fields. We describe how our research process entailed the modifications of our methods, and we consider the overlapping and sometimes opposed knowledges and attitudes of multiple stakeholders who are crucial to the uptake and scale of such new technologies for closing loops in our waste and water processing infrastructures and our food production systems. To best leverage these diverse knowledges, we suggest incremental steps for teams like ours towards an inclusive research process.

Keywords: Agriculture; Sustainability; Innovation; Inclusivity; Collaboration

Introduction

In 2016 the National Science Foundation’s INFEWS program (Innovations at the Nexus of Food, Water, and Energy) funded engineers and an anthropologist from the University of Michigan (UM) to join scholars from the State University of New York at Buffalo (SUNY) and research staff from the Rich Earth Institute in Brattleboro, Vermont in an integrative research project that constituted for all participants involved a new kind of multi-stakeholder collaboration. Targeting research and development of urine derived fertilizers (or UDFs), we built on mature experiments with source separation of human urine in other parts of the world (Kantanoleon et al., 2007; Vinnerås and Jönsson, 2013) to explore the potential value, safety and scalability of diverting urine from the waste stream for re-use as fertilizer within the U.S. We wanted to identify potential conflicting perspectives and advance equitable, efficient planning and design approaches for this inno-

vation (Guest et al., 2009). We posited education, communication and human health risk perception and management as three strands of social science work needed to move toward more adaptive food production systems. Our findings, however, indicate that those three strands each entail complex multi-stakeholder processes. To pursue them carefully requires innovations in integrative and dialogical research methods, and suggests the importance of ethnographic perspectives in an action research framework going forward. This paper documents the evolution of our methods given responses from our study participants, who seek to connect with one another and with us as partners in the innovation process.

“Integrative” as a description of research references several developments in scientific fields. In biomedical fields, for instance, proliferating “alternative” approaches to health care are recognized and researched alongside conventional biomedicine as “integrative medicine” (National Research Council, 2001). But that term also describes the braiding together in biomedicine of distinct methodological or analytical approaches in an era of big data, digital archives, and other innovation (Gligorijević et al., 2016). While in a different scientific field, our project also illustrates two meanings of “integrative”: that of alternative

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and conventional agricultural water and soil management practices, and that of diverse methodological or analytical approaches from ethnography, agroecology, and engineering (Batterman et al., 2009). A key element arising from these approaches is, further, the integration of academic and non-academic expertise (Tress et al., 2005).

Non-academic expertise catalyzed the project. To process human waste and return it as inputs to agricultural systems, the Rich Earth Institute has allied with multiple stakeholders including small farmers, community groups, legislators, planners, septic haulers, water treatment experts, builders and more. Drawing insights from these relationships Rich Earth developed its Urine Nutrient Reclamation Project (UNRP) in and around Brattleboro, Vermont. The UNRP elaborated mechanisms for urine collection (more than 100 volunteers contribute urine), storage, treatment, transport and application to pilot agricultural sites in that area. To leverage that learning and extend it from these pilot activities, our integrative research team aligns laboratory work at SUNY and UM with Rich Earth's field-based fertilizer trials (our "technical research"). Further, we align quantitative surveys with field-based participant observation, qualitative interviews and focus groups (our "social research"). For both technical and social arms of the project, field methods have more parameters to manage and analyze than do formal surveys or laboratory experiments. However, field science produces rich data, and provides insight about how to integrate results into existing systems (see **Figure 1**).

This paper presents insights from the qualitative social research arm of that collective work.

The alliance between an independent non-profit institute (Rich Earth) and universities has produced methodological innovation and multistakeholder collaboration among researchers, as well as between researchers and research participants. We describe our academic collaborations as well as exchanges with our participants beyond the academy because "knowledge is knowledge, wherever it is grown" (Ingold, 2014).

Innovations at the interface of basic and applied research (Hardin and Clarke, 2012) have been particularly informative to our methodological process. Biocultural methods in research fields integrate quantitative data-driven work with the richness of ethnographic work, including epidemiology (Roberts and Sanz, 2018), conservation biology (Hardin and Remis, 2007), the social science of medicine (Mol, 2003) and even marine microbiology (Helmreich, 2009).

An emerging literature from around the world focuses primarily on public opinion and consumer attitudes towards the re-use of human excreta and wastewater (Robinson et al., 2005; Dolnicar and Schäfer, 2009; Lienert and Larsen, 2009; Mariwah and Drangert, 2011; Simha et al., 2018). Similarly, ethnographies of new urine diverting technologies explore user experience across international contexts (Blume and Winker, 2011; also Le Monde, 2018). "Rapid ethnography"—where field work is limited and focused on user experience—is increasingly

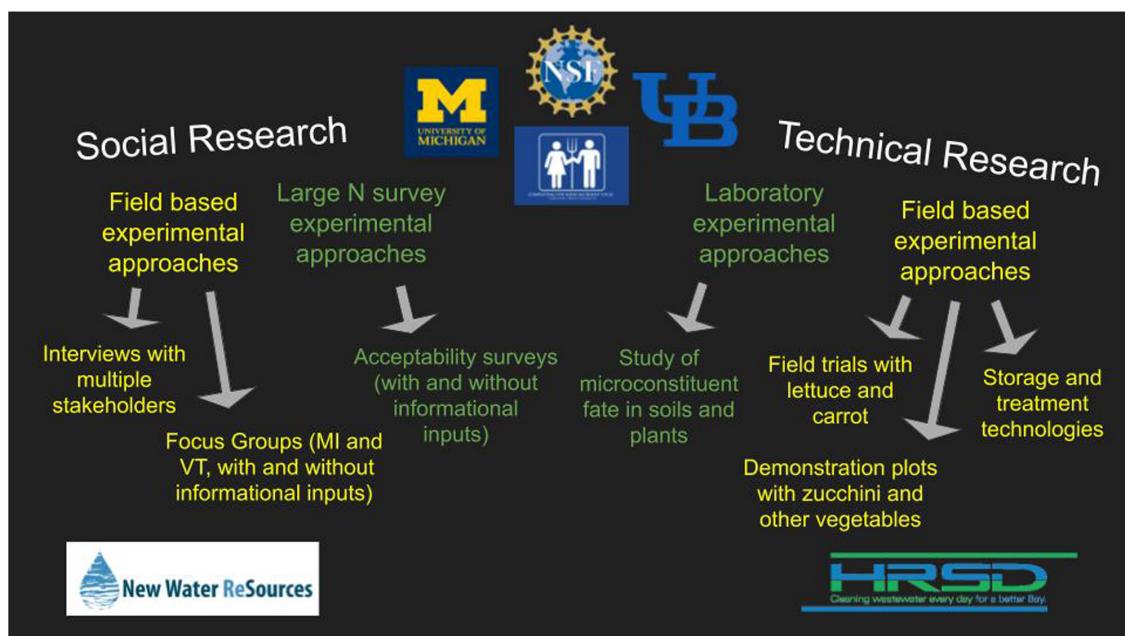


Figure 1: INFEWS project, including co-investigators and collaborating partners. The above figure represents the ways in which our integrative research team aligns laboratory work at SUNY Buffalo and the University of Michigan with Rich Earth Institute's field-based fertilizer trials (our "technical research" with supporting partners like Hampton Roads Sanitation District, or HRSD). Our quantitative surveys also align with field-based participant observation, qualitative interviews and focus groups (our "social research" with supporting sectoral partners like New Water ReSources). For both technical and social arms of the project, field methods have more parameters to manage and analyze than do formal surveys or laboratory experiments. However, field science produces rich data, and relevant insight about how to integrate results into existing systems. DOI: <https://doi.org/10.1525/elementa.408.f1>

used in professional fields like business and engineering for design and marketing of products or services with local stakeholder groups. However, as Hart et al. (2016: 402) note: "focusing [only] on primary stakeholders with vested interests in the current business and products locks the firm into incremental and sustaining innovations in existing markets rather than radical and disruptive innovations that may be necessary for entry and success." We believe elements of basic ethnographic methods can provide insight beyond those of "rapid ethnography" in multi-stakeholder work for inclusive change processes.

Informed by our cross-disciplinary collaborations, we designed a participatory research process to invite further diverse perspectives (see Cornwall, 2008). We are particularly concerned with how a participatory approach can help us understand the public health and ecological risks at stake for users of our proposed products, and redistribute expertise throughout communities of users (see Landström et al., 2011). Our research draws on a number of different fields which use aspects of ethnographic methods for participatory research, including public health, public and consumer perception, and agroecology. We utilized a "grounded theory" approach, by no means new (Glaser and Strauss, 1967) but resurgent at present, particularly in relation to participatory methods in social research (Morse et al., 2016).

Community-Based Participatory Research (CBPR) is an approach that emphasizes collaborative, equitable partnerships and the relevance of both "public health problems and ecological perspectives" to these relationships (Israel, 2019). "Community Listening Sessions" (CLS) is one method of CBPR that brings together diverse people to share their perspectives on an issue (see Erves et al., 2017; Belknap and VandeVusse, 2010). While these sessions are often less structured than focus groups, both can be used to employ ethnographic approaches for action research that attains factually accountable knowledge circulation in ways that depart from the history of extension work and unidirectional "dissemination" of information. While we did not use CLS per se, our semi-structured focus groups with people comprising specific stakeholder categories allowed conversation to evolve naturally from the open-ended questions in our interview guides. As we absorbed and reflected upon participants' responses, our thinking about the directions for future research shifted. Going forward, a more deliberative action-research effort can draw on partnerships emerging from this study. Broadly, action research is an iterative process in which research "is designed, carried out, and integrated by the participants in partnership with the researchers" (Lingard et al., 2008).

Our research also integrates community-based qualitative methods with interdisciplinary research on complex agroecological systems (Bacon et al., 2017). Agroecological methods emphasize the importance of farmer collaborations and on-farm experiments to inform research and practices, as well as participatory action research with multiple stakeholders at all stages of the research process (Méndez, et al., 2017). We assert that documenting and analyzing the perspectives of unorthodox combinations

of stakeholders (beyond established approaches to consumer or expert preferences and opinions) can happen within a research team and among its relevant research subjects. Done consistently, it can create strong partnerships for "closing loops" in our complex agricultural systems in ways that are as inclusive as possible (George et al., 2012). Our work as "the comm/ed team" proved instructive for our wider team in research fields increasingly connecting cross-knowledge integration with accountability to socially marginalized groups in technological innovation. As our data gathering and analysis proceeded, we developed recommendations for action research strategies to include multiple stakeholders going forward (see **Figure 2**).

We initially framed the social research work in terms of potential barriers to uptake of the products, technologies and processes for the use of urine-derived fertilizers (UDFs). We thought it likely that many individuals would experience visceral negative reactions when first learning about urine diversion and re-use, as has been the case with various forms of resource recovery from wastewater, such as land application of biosolids and potable re-use of highly purified wastewater (MacPherson, 2015; Jones, 2011; Mason-Renton and Luginaah, 2018).

Our team planned to frame discussions using educational tools we developed that could highlight the benefits and show how risks are minimized, as well as identify and mitigate what has been termed "the ick factor" that might impede acceptance (Galbraith, 2012).¹

Initial findings included the importance of humor as a valuable tool for communication on this topic, and of "holistic" thinking and a sense of collective responsibility as common motivations for interest in the potential of urine recycling by many different stakeholders. Additionally, while respondents often thought *others* might be uncomfortable or even disgusted at the idea of using UDFs, they rarely expressed this themselves. Many believed that transparent and accurate communication of research results that directly addressed their concerns could support openness to adoption. However, there are key information gaps across different categories of stakeholders. Dialogue thus emerged as a crucial pillar of continued work—as important as dissemination of accurate information.

We also learned from our coded interviews and focus groups of shared concerns with what we refer to as "nested risks." These start with personal, household or farm level risks, but are seen as embedded in larger-scale concerns involving hydrological, geopolitical and atmospheric systems (e.g. climate disruption). Overall, our findings suggest that the most important obstacles to Rich Earth's quest for "completing loops" in U.S. food production systems may come NOT from disgust about the re-use of human urine, but rather from distrust in how scientific information is used by business and government. This distrust could be addressed, we believe, through action research featuring facilitated dialogue across different categories of stakeholders with distinct backgrounds and educations. Given lower than predicted barriers, such approaches could

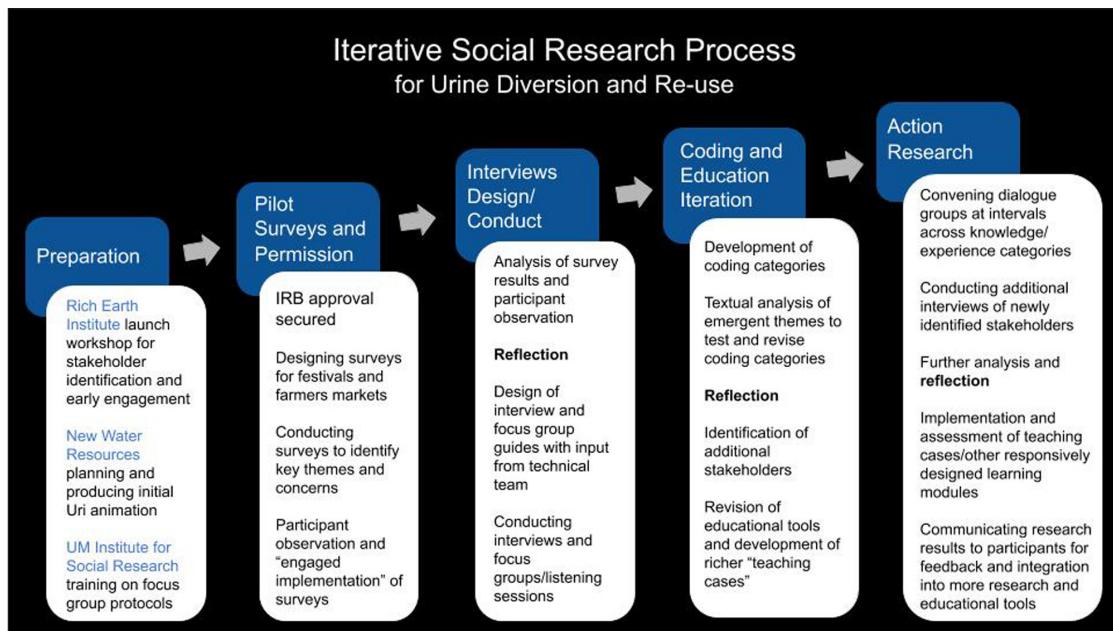


Figure 2: Increments of an inclusive social research design. The above figure indicates our process for the social research component of this project. Following a launch workshop at Rich Earth where we brainstormed to identify stakeholders (Preparation), preliminary methods included survey work engaging participants with our educational tools at festivals and markets (Pilot Surveys and Permission). Observations from these surveys along with insights from the technical research team helped to shape the content of our focus group and interview guides, each designed for a specific group of stakeholders (Interviews Design/Conduct). We conducted textual analysis of early data to fill gaps in our coding instruments to address themes—and context for these themes—emerging as most important to participants (Coding and Education Iteration). At each stage, our team reflected on learning from our prior analysis to inform the next stage (see Méndez et al., 2017, on the critical role of this reflective process). Our findings offer further methodological insight for our research; in particular, they indicate that subsequent work should engage participants in sustained (or even punctuated) dialogue across stakeholder categories as our scientific or technical understandings deepen. Conversely, this dialogue can inform research as implementation of UDF proceeds (Action Research). DOI: <https://doi.org/10.1525/elementa.408.f2>

indeed ensure that UDFs become widely accepted among alternative approaches to conventional fertilizers.

Methods: Quality assurance in qualitative work for integrative projects

We adopted a multi-sited social research design, gathering data in the two bases of the project, Vermont and Michigan respectively (more accurately New England and the Upper Midwest, since observations and interviews were conducted in other nearby states, such as New Hampshire or Massachusetts, or with individuals working in Extension across Ohio and Michigan). At an initial workshop in Vermont we used existing alliances from the UNRP to generate multiple stakeholder categories, and then designed interview and focus group guides specific to those categories. We also developed preliminary survey instruments for administering at fairs and markets, and animations to use with those surveys and with our focus groups, to explore educational tools and attitudes. After a pilot period with these multiple methods, we found the project best served by the combination of larger scale survey work with more in depth interviews and participant observation (i.e. short-term ethnography). We also chronicle a vision of adapted focus groups for dialogue within and across regions, which could be crucial to upcoming implementation

and regulation focused phases of work with UDF (i.e. action research).

For all methods—surveys, focus groups, and interviews—we noted research indicating a general lack of familiarity with UDF technologies (Ishii and Boyer, 2016), and felt conversations would be most productive if we ensured a common basic knowledge base among study participants. We thus provided brief educational information with each interview or focus group guide, including the nutrient composition of human urine, its potential fertilizer value and the initial results of yield studies on hay in Brattleboro. The guides also suggested, but did not affirm, that urine diversion and re-use may have the potential to conserve water and make wastewater treatment more efficient. This language was vetted for clarity, accuracy and to avoid bias through consultation across the research teams (both social and technical), and approved by the University of Michigan Institutional Review Board Human Subjects committee.

In addition, in our Michigan focus group, one of two New England "general public" focus groups, and in two New England farmer focus groups, an animated video was shown. The video frames the notion of UDF, unpacking its fundamental scientific features and technical contributions (nutrient composition for both agriculture and wastewater management purposes, and closed loop

systems). It uses an engaging narrator, dubbed “Uri,” in two versions (one with more detail) produced by New Water Resources (**Figure 3**).² The content of the videos was based on material developed by Rich Earth Institute over the previous several years to engage with stakeholders, and in consultation with the entire INFEWs team.³

Context methods

To explore the ways the animated video might impact public attitudes, we initially implemented Qualtrics surveys: 300 in Vermont and 100 in a pilot research initiative in Michigan. At festivals and farmers’ markets in both locations, our research team recruited adult study subjects randomly assigned to watch the video beforehand, or not. These surveys and their responses were used primarily to inform content for subsequent focus groups and interview guides. Results reported in this paper rely on the rich responses offered in these sessions, where people spoke at length. While not core methods for this study, preliminary survey work established important context, and could be built on for further research on instructional or institutional effects. We use the terms “context” and “core” to avoid the temporal assumptions of terms like “preliminary methods” for such ambitious, long term projects.

Core methods

After drawing insights about key concerns of respondents from the early surveys, we conducted four 90-minute focus groups in New England, two with members of the general public, and two with farmers. In the upper Midwest, we conducted one general public focus group, but then suspended focus group work here to prioritize interviews with key stakeholders. We felt these in-depth interviews could provide more meaningful information

in this region given the lack of existing urine collection, treatment and application to crops.

General public focus group participants were recruited using fliers and notices advertising a discussion about “the use of human waste as an agricultural resource.” Farmer focus group participants were recruited using similar language on agricultural listservs, email invitations, and follow-up phone calls to these farmers. We provided refreshments and 35-dollar gift cards. Below we refer to members of these groups as either “general public,” or “farmers.”

For the general public groups, to ensure inclusivity beyond the parameters of our existing early adoption communities, and to learn from stakeholder groups who are too often excluded from technology and policy change debates, we sought participation only from households with incomes below \$30,000/year, except for undergraduate students who may still be considered dependents of the parents/families with unknown incomes. Among the New England participants (7 women and 5 men in the two groups combined), ages ranged from 32–69. Most were white, with one identifying as “mixed” race/ethnicity. Religious or spiritual affiliations included “Christian,” “Catholic,” “other” and “none.” Occupations included two stay at home moms, a warehouse packager, a banker, a retired person, a disabled person, a farmer, a stock-clerk, and an “administrative worker.” Educational level ranged from middle school to high school/GED and some college, with one person holding a Masters Degree. The single Michigan focus group included 4 undergraduate students and one local resident of the Ann Arbor area (2 women and 3 men). This created a wider age range and geographic diversity in the “general public” category. Due to the large number of students who may still be considered



Figure 3: Still of “Uri” from the animation. The above figure is an image of the narrator, dubbed “Uri” used in two versions (one with more detail) of an animated educational tool produced by the group New Water ReSources (<http://newwaterresources.com/>). The “Uri” animation was randomly assigned to be shown to half of survey participants in our preliminary or context research, and in some of our focus groups, to assess its effectiveness in communicating basic science about urine diversion and re-use as fertilizer. DOI: <https://doi.org/10.1525/elementa.408.f3>

dependents of their parents/families, income levels were not requested.

Both farmer groups were comprised of small-scale farmers, who predominate in Vermont's agricultural landscape. The small number of total farmer participants in the two groups may have been a result of timing, as these took place in late March as the spring season was advancing. In the two groups combined, there were 3 men and 2 women, ranging in age from 25 to 63. All identified as white or Caucasian. Three had Bachelor's degrees, while the other two had "some college" education. Household income level ranged from less than \$20,000 to between \$50,000 and \$99,000. Farm size ranged from less than 6 to 300 acres. One was a certified organic farm, one "conventional," and the rest "organic, not certified" or "beyond organic." Religious or spiritual affiliations included "none," "Buddhist" and "Christian." We were not able to include large-scale commodity agriculturalists in this data set, and encourage future research with this group. We piloted our focus group and interview guides, iteratively improving them after reflection on feedback from respondents and the team members implementing them.

We conducted in-depth interviews with 13 individuals from the New England region and 11 from the Upper Midwest. Each interview lasted 60–90 minutes and addressed a wide range of thoughts and perspectives concerning the potential for diverting human urine from the waste-stream and its use as a fertilizer. Interviewees were selected for their areas of knowledge. With the exception of three farmers currently using sanitized urine in partnership with Rich Earth (identified in the narrative that follows), they were not previously connected to the Institute. Interviewees, selected for parallel stakeholder categories across sites, included environmental advocates, wastewater treatment plant operators, farmers, agricultural educators, agribusiness leaders, planners, nutrient management advisors, soil scientists, and wastewater industry engineers. Outliers included, in the Upper Midwest, two lakeside property-owners who have a concern about water quality and in New England, two legislators. One of the Midwest interviewees and four of the New England interviewees were farmers. For the purposes of our analysis, we aggregated the data from our farmer interviewees with that of the farmer focus groups. Thus, we refer to all farmer participants as "farmers" in our discussion below. All other interviewees we describe as "specialists."⁴

The individuals interviewed in the upper Midwest had an age range of 39 to 73. All of them identified as EuroAmerican/Caucasian, eight as male, and three as female. They all reported at least two years of college education; three had advanced graduate degrees. In the New England sites, the individuals interviewed had an age range of 32 to 73. All identified themselves as EuroAmerican/Caucasian, ten as male and four as female. Thirteen reported at least two years of college education, with seven having completed an advanced graduate degree.

Data analysis

We audio recorded each focus group and interview, and transcribed in full from the recording. All transcripts were verified (i.e. checked against the audio recordings) by the

researchers who implemented the interviews). We then had two research team members who had not conducted the interview code independently of one another using a common, collectively generated and iterated coding guide. At the start, we developed 17 codes for key themes, each with a number of sub-themes, some of which reflect a scale as in "low," "middle," or "high" values (Bernard et al., 2016). However our "grounded research" method meant that codes were incrementally elaborated and revised in light of both original research questions for the project but also knowledge and concerns that emerged from the interviews.

Each transcript and its coding results, consisting of comments (in Microsoft Word) written by separate coders, were then compared using the review function "compare documents." We merged coded transcripts for each focus group or interviewee into a single master document for analysis and reflection by the social research team. This enabled us to tweak our coding categories, if we identified important diverging code uses or missing codes for recurrent concerns.

To perform further content analysis, we then ran a Visual Basic for Applications (VBA) script⁵ to extract the coded comments from each master document along with associated excerpts, page numbers, and coders' identities into a Microsoft Excel spreadsheet. We selected this method as against software packages like Atlas.ti or Nvivo in part for its virtue of affordability and accessibility to nonacademic research partners. This aggregated the coding results from all focus groups and interviews to observe the (co)occurrence of our codes.

The total occurrence of each code is not necessarily equivalent to the number of statements made by participants on each coded theme, as more than one coder may have used the same code for the same excerpt. Rather, it suggests strong analytical clarity or analytical consensus, in addition to relative frequency. Therefore, in our writing we do not report specific quantities of the number of statements made by participants, but rather use semi-quantified language empirically anchored in the spreadsheet results. "Most" or "many" thus describe responses proportionately representative of the data, and "some" or "few" describe outlier instances that may not align with strong trends in our corroborative interpretation of the excerpts (for more information and sample research prompts, see Supplemental Materials Text S1).

Our approach to interviews is in the tradition of ethnography—open ended, with semi structured guides and careful attention to long form narrative responses for their wealth of information both about processes of innovation and personal attitudes or beliefs about those processes. Because we were a collaborative, interdisciplinary team, we did make efforts to code and corroborate our analysis. Harry et al. describe a similar process:

A sample set of transcripts were read by a team...who met twice a week for three weeks to compare their separate coding of the same data.... As a result, some codes were condensed into one and new codes were developed, as commonalities or distinctions among the meanings of similar data points became clearer....

We made no attempt to develop a numerical reliability rating, because our goal was consensus, with each point of difference being debated and clarified until the group agreed on appropriate usage of the set of codes. (Harry, 2005: 6 further referenced in Saldana et al., 2016).

The description above is by no means the only one in qualitative methods texts to acknowledge both software-based tools for coding and individual researchers' or research teams' insights and capabilities for inference.

From the start our qualitative field team's contribution to this integrative project was foreseen as groundwork at local and regional scales toward broader national scale survey and experimental methods (Alex Segrè Cohen et al. U. Mich, personal communication Jan 17 2019).

We also anticipate deep dive work to explore discrepancies or puzzles in findings from "larger N" studies across regions. This is crucial because many attitudinal and practice nuances can be lost in larger scale survey-based studies, as can broader conceptual trends or even moral and ethical concerns. For instance, more of our respondents than anticipated expressed a sense of both personal and collective responsibility for mitigating environmental harms. This was coupled with constructive questions about who—both jurisdictionally and morally—should take on those responsibilities.

In response to these findings, it is incumbent on our project team to consider opportunities for "inclusive innovation" that honors our subjects' own efforts at creating more sustainable systems (George et al., 2012). We hope these concerns and motivations among our respondents can be building blocks of informed partnerships around urine diversion and re-use going forward, rather than limiting rich ethnographic work to the initial, formative phase of such an ambitious project with system change implications.

Results

Communication about new technologies, early adoption, education and implementation are all iterative processes. As people learn about the possibilities, they have questions and concerns. As they adopt new methods, challenges and opportunities arise which influence the type of communication and education that is needed, potentially leading to more adoption, and so on. We discovered that our research instruments and approaches also had to be iterative, to respect what we were hearing from our study subjects, and to be accountable to their changing experiences.

Expanding Coding Categories to Account for Emergent Meanings

As an example of this iterative process, we adopted a coding category for "humor," which we found to be widely varied in our transcripts. People may laugh when talking about something a little uncomfortable, but often, in our conversations, the laughter was positive or became so. In the focus groups, humor seemed a way to connect with others in the group, in a shared, enjoyable experience, as they learned about something new.

It was also a reminder that even when faced with system changes, humor can be an affective resource. Indeed it can be a response to shared discomfort or initial resistance to reflect on new approaches that seem taboo. This links UDF work to a reimagining of our uses of human waste in general.⁶ When asked if she would serve food fertilized with a UDF to her family, one respondent offered: *"I would do it."* Interviewer: Yeah? *"Yeah, I don't know. I like to push them [laughs]"* (General Public Focus Group 1, 2017).

Our coding category of "holism" emerged from focus groups and interviews suggesting that the introduction of UDFs needs to be considered within larger ecological and economic contexts. Holism, as we use the concept here, refers to the idea that individuals, society and the environment are intertwined and interdependent. We do not mean to resurrect structuralist notions of holism that belie the powerful science of perturbation, resilience and change in coupled human natural systems as it accommodates practical management challenges (Cinner et al 2019, Oldekop et al, 2019). Rather, the term "holism" flags succinctly our respondents' assertions of interconnectedness between their household needs and wider systems, and also draws attention to widely shared motivations for interest in UDFs.⁷

However, representatives of the general public in our focus groups raised concerns that production and processing of urine to meet safety standards could negate the benefits of "closing loops." Noted one participant,

...urine derived fertilizer...just seems like it would still be an energy intensive way to get your fertilizer. So if you want to cut out...if you want to get the greenest possible formula, if straight urine is still safe...I don't know if I'd prefer that to urine-derived fertilizer (General Public Focus Group 1, 2017).

Farmers, while also invested in resource conservation, by necessity must consider the cost of UDF fertilizers relative to conventional ones, and the precise metrics of water conservation or other benefits that might derive from using them. That said, one third-generation dairy farmer noted the wider issues at play:

...anything that we as a civilized society can do to reuse anything in the waste stream is a positive. I mean, when you look at how many people there are in this world today, I think we have to come up with new and innovative ways to use all of the waste stream, that those people create, and that includes human waste (Farmer Focus Group 2, 2018).

Another farmer's comment also reflects interest in holism and conserving resources:

...we can create the things that allow us to sustain our communities, the fertilizers to [grow] the food that feeds the people; if we can do that locally, then we're a lot more resilient as a community. So I do think there's a lot of value in trying to localize [UDF] processing (Farmer Focus Group 1, 2018).

Among the specialists we interviewed, a Massachusetts environmental advocate who heads a large water conservation organization also noted a chain of potential benefits that urine recycling and re-use could have in different but interconnected ecological systems.

...whether it's the amount of energy use in wastewater treatment, the amount of water used to make something, or the amount of energy that you use... there are very clear potential climate benefits to something like this. There are very clear aquatic benefits to something like this... because you are still going to be confronted with how you use that nitrogen, wherever you get it from, but I think the assumption is that you're going to be able to have more strategic use of nitrogen (Massachusetts Environmental Advocate, 2017).⁸

The advocate noted that communication and education efforts will need to accurately and transparently address benefits and also report research results concerning immediate household-level and wider-level nested risk categories we have described elsewhere.⁹ Only then can individual, household, farm or civic/regional measures that might have aggregate effects in the future seem worth the effort to implement.

A few participants who saw the Uri animation also noted UDF's potential to reduce nutrient loading in waterways and thought that would be a key motivator for people familiar with those issues, but they would need to see support for that claim:

[The video] mentioned briefly like algal blooms, but...I'm not sure how this would help reduce those? I mean... if there's a claim to be made that's credible that it would reduce those that would be really important. Especially like in Michigan where we hear all about Ohio's Lake Erie problem. I think that's a good one to touch on. But I'm not sure if it actually can help with that (General Public Focus Group 1, 2017).

Such uncertainties will challenge adoption until more field trials address best practices for the agricultural application of UDFs to minimize nutrient run-off and leaching, as well as a number of other research needs identified by our interviewees.¹⁰ The technical team has addressed the potential for antibiotic resistance to be transferred to soil organisms (Goetsch et al., 2020), and is now conducting a soil incubation study analyzing the fate of pharmaceuticals in soils over time. The aim is to quantify levels of microconstituents and their potential "risk" to human health and/or the environment, complementing previous field studies (Krista Wittington, University of Michigan, Personal Communication, Sept 5, 2019). In the meantime the social research team is considering how best to make results from such trials (or scientific results about nutrient leaching, as they emerge) more accessible and relevant to key stakeholders such as farmers, specialists, and the gen-

eral public in early adoption areas for UDFs, and beyond. These results can also inform future interview guides and educational materials used to facilitate dialogue among stakeholders.

Multiple stakeholder perspectives reveal new research directions

Our respondents have encouraged us to link innovations in personal hygiene and food production to fine scale research questions about biological and chemical contaminants or to larger scale hydrological and climatological trends. Their most frequently expressed concerns relate to the potential presence of micro-constituents in urine such as pharmaceuticals, including medications for cancer and diabetes, hormones, and antidepressants, as well as opioids and other non-prescription drugs (Stadler and Love, 2016). This echoes similar concerns by the public and farmers in Europe (Lienert and Larsen, 2009), and is being addressed by the tech team of this research collaborative.¹¹

In our dataset, concerns for personal health (i.e. microconstituents being taken up by food crops) were common, but balanced with wider equity concerns. For instance, respondents raised questions about the ethics of using bodily fluids should large companies end up profiting from the use of human urine for fertilizers. Additionally, while members of our focus groups did find value in regulatory approval or certification for decision-making about UDF, many of them also worried that they might somehow be taken advantage of as this concept is developed. They suggested that people should perhaps receive some kind of subsidy or credit off of their water fees to reward them for recycling urine. In general, our respondents urged transparency as urine diversion is scaled up, and wanted local decision-makers, such as town managers and local farmers, to be involved in the process.

Our interviews and focus groups also suggested strong interest in research about how urine diversion could address concerns with compromised water quality. For example, one environmental advocate and lakeside property owner was working to preserve one of northern Michigan's inland lakes; these lakes are heavily impacted by surrounding septic systems. They thus saw UDF's potential to reduce nutrient loading as a promising opportunity for their community:

We're in such a state here without sewers, you know, it looks like we'll be mainly septic for a long, long time. So if there's a way to improve that, lessening the nutrients into the lake, I think that's fantastic... I mean, it would ...[give us] hope not only to maintain the water quality as it is, but to improve the water quality over time (Michigan Environmental Advocate, 2018).

However, with regard to the agricultural use of urine, some respondents recognized the potential for environmental harm, should UDFs be applied during a heavy rain event. For example, one focus group participant noted that:

...some of that product is going to dissipate into the groundwater, potentially people's watersheds... it depends on how good this product is and have they addressed all those health concerns, that's a concern too, because now you've taken it out of just being [in] plants... being into the water system too... (General Public Focus Group 2, 2017).

Farmers, agricultural educators, and several of the other specialists raised further questions about watershed level concerns. All too often scientific and technical uncertainties about causes of harmful algal blooms, for instance, can lead to a kind of "blame game" which, unaddressed, can pit urban against rural residents. This occurred to some extent in the widely publicized recent referenda in the Upper Midwest on "lake's rights" based on the problems of water pollution from agriculture. However, some of our respondents insisted that non-farm nutrient loading can be equally or more important in broad water systems outcomes. As one agricultural extension specialist working across Michigan and Ohio noted wryly:

Toledo's gonna do...some kind of a vote to, you know, their right to exist in a clean environment and enjoy Lake Erie in spite of everybody else...when they're dumping probably as much stuff with their storm sewers, their stormwater and their sewer, bad sewer connections! [Citizen groups] ...all have this attitude that farmers should be doing everything to make their life better. Make their air better, make their water better, you know. And then they're spraying all this stuff on their land. Do you know the maximum allowable application rate for glyphosate? It's a quart per acre. Typical application rate is a pint per acre...And you talk to most of these people and they're putting WAY more of that stuff on their lawns than any farmer is on his fields (Michigan Agricultural Educator, 2019).

The types of assumptions this respondent mentions about the rural-urban divide are present with other water quality issues, from nutrient loading to pathogens like *E.coli*. Data on various contributions to water quality problems indicate considerable variation from region to region and even within small but topographically varied areas (Ghane et al., 2016). From our interviews one sees how these issues inspire some of our respondents to cite scientific work in their efforts to better understand causality. This comes with risks of contributing to wider conflicts such as those between urban and rural worlds, or between farmers and environmentalists in a polarizing national political context. Notes one Michigan waste-water treatment specialist:

Nutrient loading is obviously impacting the Great Lakes...harmful algal blooms.... I think people, waste-water plants, have done a better job at nutrient removal than the farmers.... My understanding is now based on some research...at State...that... even

the E.coli that's being found in the water after super-storms, is not human. It's pig and calf. Same with the nutrients. So until we can get the farmers—who have a special place in the world and our hearts—on board with this, it's gonna continue to be a challenge (Michigan Wastewater Treatment Plant Operator, 2019).

The science itself evolves only incrementally and often supports neither "side" in most debates, but points to the fact that many actors are implicated and greater accountability is crucial (see US EPA, 2019 and USGS, n.d.). The comments here reveal how normative concerns about ethics and equity are situated both regionally and socially according to the various stakeholder groups under varying policy or political framings of problems. Heartfelt expressions of community concern among many of our respondents about water use, pollution and protection enhanced our overarching research agenda by encouraging integration of food systems with water systems of various types in our research framework. They also informed our understanding about gaps in knowledge across stakeholder groups as these reflect and reveal infrastructural, institutional, and social differences.

Possible water quality advantages conferred by urine diversion (whether destined for use as fertilizer or not) prompted us to explore differences, if any, across sewage and septic systems. Concerns such as those of the lakeside property owners interviewed in Michigan have led us to consider future research in more residential sites—even second home communities—alongside agricultural ones, both in Michigan (on inland lakes) and in New England (on Cape Cod and in small villages). For example, Rich Earth Institute partnered with a local regional planning agency to conduct a feasibility study of urine diversion for two riverside villages facing wastewater challenges, engaging community groups in the process.¹² The challenges of reconciling innovation processes across such contexts are not negligible. One environmental advocate (2017) noted:

...when you're crafting aquatic standards for nitrogen in order to fix Long Island Sound, you're going to make a decision for Vermont and New Hampshire, because they have responsibility for that system, 200 miles away. But that decision should also reflect how a local aquatic ecosystem will respond to a number. So you have to think about what are nutrient criteria, biological definitions of healthy waters that mean something for Brattleboro, as well as Old Saybrook, [CT] (Massachusetts Environmental Advocate, 2017).

Also, as an agricultural educator noted, different parts of Massachusetts have different regulations:

Cape Cod has its own Extension service. In fact, Cape Cod has different and more stringent nutrient management regulations on their own area, because

their water, they're in a very sensitive area. So each of their townships and counties have their own set of regulations (Massachusetts Agricultural Educator, 2018).

Tensions between water conservation and agriculture exist in both regions; however, in New England regulations mandate nutrient management plans for farmers (under the auspices of agricultural agencies). As the respondent above suggests, this establishes levels of nutrient inputs to waterways which are causing wastewater treatment plants and others to determine how best to attain those standards. Such implementation challenges, as well as monitoring and further adaptive management in diverse systems will require training materials that can be updated as time goes on. Materials might need to be adapted to various types of stakeholders and their concerns if we are to move toward demonstrably better outcomes in our food and water systems. The work of producing such materials could also address innovation in dialogical research methods, which touchpoint with key partners over the course of technology shifts.

Ascribed attitudes and dialogue in inclusive innovation
 One of the striking results from this research was how often individuals said that they themselves were comfortable with the idea of urine diversion and re-use but they imagined that others would feel differently. We term this "ascribed attitudes" and discuss here their effects on educational strategies going forward. We coded ascribed attitudes on a scale of believing others would be "opposed," "open in some cases," or "enthusiastic." Among farmers and the general public, we noted that there was often a personal openness to the concept, but a belief that others would be opposed. Significantly, however, most felt that these attitudes could and would change over time. The specialists often thought that, once informed, others would be "open in some cases."

In our general public focus groups, individuals often said that they themselves were open to this idea, but they imagined their friends and neighbors might feel differently. For example, one focus group participant said:

I think most people view urine as a waste product, that stinks, that is dirty, that needs to go far away... you know, and, associated with food... that would make people disgusted... I think this group, perhaps is more aware of the situation, so it doesn't have quite that effect...but the larger population? (General Public Focus Group 2, 2017).

However, most respondents felt that if people receive the answers to their questions, attitudes will change. One remarked:

If you don't give them education, the statistics, the stuff they want to know, then maybe their first reaction would be like 'ew' but I think people are willing to hear reasonable arguments about why something

[like this is worth considering] (General Public Focus Group 2, 2017).

Participants also acknowledged that they themselves thought urine diversion and re-use might be a bit uncomfortable at first, but over time it would become normalized. One said:

At first I was kinda like, 'oh that's kinda weird,' but...would not prevent me from doing it. Like I still recognize it as valuable...I'm thinking of like my family and friends ...and I could see them also being like 'that's kinda weird' but being easy to convince that it makes sense to do (General Public Focus Group 1, 2017).

Among farmers interviewed, one of the biggest concerns with the use of UDFs was public perception among their customers. Most farmer participants in focus groups expressed cautious interest in UDFs personally, but were concerned with taboos they expected on the part of others. In particular, they worry about what they believe may be their customers' attitudes and anxieties. One said,

I think all people should be on board with trying to figure out how to do it in the safest way possible but I also think that there should be a lot of awareness and reasoning around it so that it doesn't affect the farmers who are trying to reach markets ...where people might have some concerns about it (Farmer Focus Group 1, 2018).

Others felt that if the science, safety and environmental benefits of UDFs were communicated effectively, their customers could become supportive. One reflected:

...if it's really communicated well, and everyone is really reassured that this is safe, this could actually be a positive thing for customers... people want to reduce their environmental impact and if they see that, you know, we're, we're handling waste in a way that is beneficial, that could actually be a reason why people would want to support us (Farmer Focus Group 1, 2018).

Specialists, as compared to the public and farmers, more often thought others would be open about this, once they learned about it. Over the course of many of our interviews, interviewees themselves became more open, even as they raised new questions and offered suggestions for implementation or further research. One Vermont planner felt that urine diversion deserved attention among colleagues:

Right now we're putting wastes into landfills that don't need to go there and wastes into the water stream that potentially, if used in a different way, wouldn't be wastes. I think that's a discussion worth having with communities that some would be open to (Vermont Planner, 2018).

This planner thought others might at first be opposed simply because urine diversion is new: *"There's...a cultural bias toward water-based systems, even though ...when you look at the cost of building a community wastewater [system] the piping is the most expensive piece."*

The planner made a second important point, about the activation energy needed for almost any innovation, noting: *"... it's not what people are used to, so they're resistant to it."*

But specific regulatory hurdles for UDF, the planner cautioned, could constitute obstacles at various scales:

A homeowner might be open to it because there's a clear process for homeowners, but for a general store, or a commercial business, the rules are really unclear [so] even if someone might consider it, lack of clarity I think frightens them away.

Could that be counterbalanced by the possibility raised by some legislators, planners and wastewater treatment professionals that diverting UDFs could save money in treatment plant upgrades? Such savings, they argued, could make the general public more open to it. Many of them underscored to us how explicit regulations often determine what innovations are actually implemented. Such observations further recommend structured, sustained dialogue across different relevant stakeholder groups and agencies within pilot regions to better understand these differing information needs, linking them to changes in regulatory processes.

Of course, the way these conversations proceed depends upon one's value and frame of reference. For example, the New Hampshire soil scientist noted that,

...how we evaluate [this new activity] depends upon what we value and what we're looking at at any one time, you know? Do I value diverting urine from the waste stream? Of course. AND, you know, I'd like to know what the effects would be on agricultural systems if this urine is being used in agricultural systems. I'd like to know what the effects would be on soil microbes, so it depends on...the frame, or the entry point to the question, you know, how we evaluate it, whether it's critically or positively (New Hampshire Soil Scientist, 2018).

The soil scientist contrasted this with how a colleague specializing in wastewater treatment would think about this, supporting our insight that innovation in this area will require dialogue across specializations and stakeholder groups in ways that acknowledge different perspectives and "ways of knowing" (see Martinez-Torres and Rosset, 2014). Interviewees had valuable suggestions for communication and educational strategies that they believe would be most effective within their own communities. For example, a Massachusetts wastewater treatment plant operator noted the "resource recovery" language that is becoming important within that industry: *"[We are] a resource recovery industry. We make clean water, we recover nutrients, we generate electricity, and so that's that frame*

that we are very familiar with and support" (Massachusetts Wastewater Treatment Plant Operator, 2017).

The Massachusetts environmental advocate (2017) suggests storytelling components of the kind our methods capture can have public opinion benefits. For example, they noted that their constituents are concerned for the economic viability of local farmers:

You know, we're blessed here that over decades we have created a culture of caring [for] our local farmers and local agriculture, and we understand them, and they're present. So maybe that is a compelling narrative.

This interest may inspire consumers to understand how and under what conditions UDFs could make economic and infrastructural sense for farmers in their day-to-day and month-to-month operations.

Many specialists we interviewed told us that we needed to talk to "so-and-so" for a different perspective that was important to understand. Or, they would note that another group or agency might put up roadblocks to potential implementation of innovative strategies such as the use of UDFs; they stressed the need to put people of such different perspectives in the same room to address these gaps in understanding.

Discussion: Knowledge exchange as action research

Many of our findings are complex; some are counterintuitive, yet they are constructive for further work on these topics. For communication, animations and other brief oral or print explanations designed to explore the impact of education on attitudes were useful, but not as comprehensive or engaging as might be expected. We learned from our mixed methods that people don't need (or don't only need) animations and other didactic content. True, in our initial surveys at festivals and farmers markets, 87% of Vermont respondents and 100% of respondents in Michigan agreed with the statement: "The Uri animation would be a useful educational tool to help people understand the issues around urine diversion and urine-derived fertilizer." Yet in both surveys and focus groups, while we observed somewhat more favorable responses among participants who had seen "Uri" than those who had not, the differences were not substantive. We will thus explore media-rich teaching materials that are more complex, such as learning tools based on case studies, for use among different groups; we are currently running pilot assessments with such tools.

Overall, the focus group and interview data suggest that respondents seek not only content, but conversations and social processes to express their concerns about safety in linked food and water systems, and about the viability and integrity of natural systems. For example, one focus group participant described the limitations of animations as an educational tool: *"I know that they do it with all sorts of educational videos, but I don't know that you need to have an animated whatever... And it's like... I can absorb the information without being talked to by a drop of urine."* Several

participants agreed, with one adding on, "*I thought my kids would have liked it,*" and another explaining, "*I mean, it made us all chuckle, we all chuckled, but yeah... it didn't answer all the questions*" (General Public Focus Group 3, 2017).

Our focus groups and interviews enabled informants to acknowledge the comedic elements of "peecycling" (a term that was used in the Uri animation) in ways that may be more effective at mitigating discomfort with the idea and practice of UDFs than didactic educational outreach. This does not mean there are no notions of taboo with the use of human waste; rather various levels of discomfort can give rise to "liberating" humor, which in turn can shape facilitation strategies for further information and education. Collaborative resources for using "liberating structures" are developing that offer inclusive group facilitation methods to harness the elements of humor and spontaneity to create trust in group process; our findings support using such tools for forward communication and education work.¹³

What we initially conceived of as "focus groups" might better become "listening sessions" or "dialogue groups" where humor plays a role, along with respect for the process of knowledge exchange, such that multiple stakeholders feel they are being heard, that they indeed have a stake in the "expertise" being constructed such that research to answer their questions can move forward. Further, it is in this exchange that questions of ethics and equity are likely to emerge, and opportunities to address such issues present themselves. That is to say, educational and communication research can be braided together, and moved beyond formal classrooms into the civic and professional continuing educational needs of communities of conservationists, professionals, farmers, consumers, and more.

Reviews of technological transformation as social process have long been important for those working in agriculture; in recent decades they have moved beyond dominant extension modes (which grew out of the green revolution in the early twentieth century), toward more relational approaches. These include bounded rationality, diffusion, and reason-related theories, where acknowledgement of collaboration in innovation seems ascendant. Botha and Atkins noted Consumer Behavior Theory (as early as their 2005 review cited below) as a newer paradigm whereby "the decision to adopt is influenced by the level of consumer involvement in the innovation." Interdisciplinary knowledge and emerging communication skills for sustainability professionals emphasize the importance of horizontal learning, or structured dialogue across distinct knowledge communities to involve them with one another at design stages, rather than implementation stages of a given innovation (Vedrin and Hardin, 2016; see also Sterling et al., 2017).

These "knowledge dialogues" (or "diálogo de saberes" as Martínez-Torres and Rosset, 2014 call it, based on the foundational work on dialogical method by Freire in 1970) can work at both curricular or disciplinary or community/institutional levels. In any of these contexts, active learning is better than passive absorption of content. Expertise in technical, ethical and policy domains

necessary for transformations of our infrastructures is best seen as cumulative, collectively constructed, and elaborated in conversation (Hall et al., 2018).

Hence "focus groups" shift from their initial methodological values for "pulse taking" and data collection about public opinion to a facilitative role whereby they can foster knowledge exchange among emergent categories of actors who are crucial for effective system change. These conversations should feed into communication and education tools. In sum, our initiatives should prompt action, assessment and reflection, communication, then further action. Dialogical and action-oriented education can thus be effective in revealing the most viable and valuable practices and implementation strategies appropriate for urine diversion and re-use, and can, at the same time, help us to understand how attitudes and beliefs concerning how we manage human urine can and will change over time.

In this sense, the complexity of ethnographic and qualitative social fieldwork parallels that of UDF application field trials, with their variations in microclimatic and soil conditions, biological differences across crops, and so on. Both kinds of field science—social and ecological—are crucial for understanding the potential for uptake and scale as well as downstream implications and information needs for actual farmers. In the medium term, both for the technical team's work and for the social research team's work, we have found more structured lab and survey approaches to be useful for generating findings fast enough and with enough clarity to bolster project momentum and inform field research. On the technical side we are initiating soil incubation studies where parameters and inputs can be more tightly controlled. And on the social research side paid market surveys have taken useful pulses about acceptability of UDFs. Going forward, we anticipate the need for more fundamental research on UDFs in coupled human/natural agricultural systems. These pilot field studies are pillars for such continued work.

Limitations to this study merit consideration before concluding, in part because they reflect what Méndez et al. (2017) have described as wider limitations for the development of dimensional social science methods that articulate with multistakeholder complexity. First is the small number of focus groups, particularly in the upper midwest where that work remains to be completed pending further implementation of UDF use there. By the same token, we want to include more interviews with larger-scale farmers in New England, and that of more farmers, of any scale, in the Upper Midwest. Their interests may well be different than those we included here and further research should address this gap, bringing more parity to the two regional datasets and mitigating the potential effects of unique features across the sites where we are conducting research. Méndez et al. (2017: 705) describe three barriers to this kind of methodological evolution: "the need for time and resources over longer periods; the complexity of multi-actor process facilitation; and institutional barriers within the academy and development organizations...." These merit attention in upcoming integrative research design work for this and similar projects.

Our interview data sets are more balanced than our focus group sets across the two regions. Overall, relatively small numbers of individuals were interviewed, and with a relatively narrow demographic range of respondents. Some potential interviewees we contacted did not agree to participate, which could have fostered a slight bias toward openness to the concepts of urine diversion and re-use among our interviewees. However, in both recruitment and facilitation of focus groups we emphasized that we wanted to hear all viewpoints, and some interviewees did participate and express skepticism or negative feelings, which appear in the transcripts.

A final limitation may inhere in our analysis of coded data through aggregated excerpts in Excel spreadsheets. This revealed interpretive consensus and co-occurrence of codes, but did decontextualize the data to an extent and may have fragmented participants' responses depending on each coder's style. However, the researchers who read and interpreted the coded data were also informed by earlier stages of the analysis, including the review and discussion of complete transcripts. Also, given the small size of our data set, researchers had a strong familiarity with each transcript. Using this analytic method at a larger scale or on its own without a deep understanding of the context of the data might have limited interpretative depth and comprehensiveness. This paper, we hope, can serve usefully as baseline context for subsequent larger scale and/or longitudinal study within and beyond the pilot regions.

Conclusion

In our vision of action research going forward, individuals from a wide range of backgrounds and experiences join with researchers to inform ongoing science around alternative waste management approaches, including UDF treatment and processing, and to shape implementation, regulation and policies around such projects. We suggest that such "cross-knowledge dialogue" among multiple stakeholders will be crucial to identify how UDF can be implemented in septic versus sewage systems, urban versus rural contexts, and among small versus large scale agricultural production. These methods may help to bridge some of the knowledge gaps and potential polarizing factors we have identified. In so doing, we can address the unexpected challenges revealed in this study whereby it is distrust—more than disgust—that impedes broad adoption of UDFs as one key new technology for making our food and water systems more resilient, adaptive and sustainable. Scientific and technical expertise must demonstrate accountability to other forms of knowledge and practice; partnerships like the one described here among stakeholders and across types of organizations can model and foster such relations.

It is clear that scale and geography will influence patterns of adoption of urine diversion and application of UDFs. Place-based collection of information about experimentation, iteration, and implementation of new technologies will be valuable. Given the heterogeneity of the US agricultural sector, more longitudinal coupled human natural systems research would be optimal within our

pilot regions, and among them and other pilot sites worldwide. Such results would enable accurate and compelling communication about the potential benefits of this innovation in specific situations, while remaining accountable to concerns of local stakeholders.

Our respondents have drawn our attention to the sorts of natural experiments already underway by communities, conservancies, agricultural associations, commodity groups and more to implement more sustainable practices in the two regions we studied. Their experiments, fueled perhaps by shared "holistic" motivations, have already given rise to partnerships: for instance, between farmer cooperatives and river conservancies, or community health campaigns. Many of our research subjects described specific land use practices that may either protect or contaminate our food and drinking water systems on a regional or even individual farm basis. UDF use can in many cases complement or extend such existing work.

Listening sessions or dialogue groups within and between such groups could enable that kind of specific input to experimental and technological implementation, since "uptake" of technologies like urine diverting toilets, treatment and storage tools and transport vehicles, or fertilizers made from urine, is so complex and varied. Insights from other studies using a dialogical approach to focus groups indicate that they may be one important method for bridging governance and regulatory divides in food systems change (Sonnino et al., 2019). They can also provide opportunities for new research results to be shared and discussed, ensuring that responsible conduct of research norms also account adequately for multiple stakeholder scenarios.

Finally, such qualitative methods can catalyze informed debate about the implications of innovation for policy and planning in contexts as distinct as urban, suburban and rural communities with a range of septic, sewage and other waste management histories. We know that historically such changes in US food and water systems have been wrought with inadequate public dialogue (Tarr, 1996; Smith, 2013). Today's entangled choices about how to handle waste from human bodies in relation to water infrastructure, home and personal hygiene, and agricultural or hydrological systems will be studied by future scholars in much the same way as the agricultural green revolution is studied today. We are working to ensure they find a more complete archive about consultation and collaboration with multiple stakeholders, for that is the crux of such change processes—indeed of a new generation of research projects like this one.

Data Accessibility Statement

As noted in our original proposal for this research, the PI (Dr. Love at U-M) leads the development of a coordinated data storage, access and dissemination plan for all project participants. All electronic research data files generated as part of the project are stored in M+Box, a shared cloud-based system that can be integrated with Box storage between universities. Partners outside of U-M and universities have also been granted access to the shared storage space.

The team publicly release relevant data as early as possible but no later than 30 days after the publication of timely scholarly journal articles coming from the project. Other products are public domain and will be accessible via the Rich Earth Institute Website. Public access to data and other products not on the Rich Earth website will be available through DeepBlue (<http://deepblue.lib.umich.edu/>). Digital forms of data and products will be maintained in DeepBlue for a minimum of three years after the project is complete. Non-digital forms will also be stored in the PI's office or laboratory for at least three years. From experience, we anticipate that data will be available longer than 3 years. DeepBlue is a free service to members of the University of Michigan community, and access to data in DeepBlue by the public is also free.

There will be no restrictions on data re-use or re-distribution given our open access policy noted in the original proposal. An acknowledgment of the source of the data, as well as the funding agency (National Science Foundation), will be requested of all users and clearly stated when data access is provided.

For this specific article, the team will ensure that all relevant verified transcripts from focus groups and interviews, in their merged and completely coded form, are available on Deep Blue, along with the Excel spreadsheets used to run the analysis of co-occurring codes and to track the relevant quotes from research subjects across transcripts.

Notes

¹ We are inspired by quantitative assessment of comparative risks as found in biomedical research (for instance, Hazard et al. 2018), and we aspire to develop more mature risk rubrics as tools for key decision makers, producers, and consumers of foods or other crops made with UDFs.

² Our collaborators at New Water ReSources (<http://newwaterresources.com/>) shared successes from their public perception campaigns about recycled drinking water in Singapore, and reviewed literature from studies of narrative versus/and quantitative information about global problems such as resource scarcity, global migration, and humanitarian disasters that indicate how human brain function favors strong narratives over scientific summaries for galvanizing action (Harel et al. 2017).

³ The animations can be seen here (last accessed August 28 2019) [<https://www.youtube.com/channel/UCSRKi2j0HQvVNRoC2DKV2eQ>].

⁴ The comments of one farmer who heads a farm-based environmental advocacy group were analyzed in both our “farmer” category and our “specialist” category.

⁵ We did not write this VBA script; we modified the code and method from Carsten Knoch, available here: Qualitative data analysis using Microsoft Word comments. *Carsten Knoch: essays + ideas* (blog). February 24, 2018. Last accessed October 20 2019 <https://carsten-knoch.com/2018/02/qualitative-data-analysis-using-microsoft-word-comments/>.

⁶ Shawn Shafner’s performances with “The Poop Project” combine idioms of musical theater, comedy and direct

address. They exemplify the power of humor to catalyze conversations about personal and system change: <http://thepoopproject.org/> However, our work with focus groups suggests that respondents may be more comfortable with urine than feces as a topic of both amusement and potential adaptation of our hygiene and food systems.

⁷ Human ecology and systems thinking at local or regional scales built on empirical studies like Harris’s (1966 and 1978) analysis of the use of “sacred cows” in India as an energy capture system, and Rappaport’s (1984) work on the timing of pig culling in highland New Guinea as it related to horticultural productivity and the energy needs of human communities. The emergence of world systems theory, political ecology and disturbance ecology in the later 20th century revealed limitations of such tidy models of closed loop systems, fostering instead approaches across scales like Vayda’s (1983) “Progressive Contextualization” which is closer to our approach.

⁸ Our informed consent procedures for this study provided confidentiality for all participants in order to support their uninhibited comments. While most of our respondents were comfortable with being identified, some were not. For this reason we have chosen to anonymize all respondents in this paper.

⁹ Our team has written another paper, in prep, analyzing distinct coding parameters from our dataset to address respondents’ notions of the “nested risks” at various scales that such innovation entails (Schreiber Personal Communication).

¹⁰ While uncertainties remain about the potential of agricultural applications of UDFs to reduce nutrient loss to waterways, it is already clear that diversion of urine from the waste stream can reduce nutrient flows into wastewater. In other words, urine diversion can reduce wastewater nutrient emissions, and may or may not affect agricultural emissions. (Noe-Hayes, Abraham, Research Director, Rich Earth Institute, Personal Communication, September 24 2019.)

¹¹ Our technical team finds that while pharmaceuticals (especially those most commonly consumed such as caffeine and acetaminophen) are taken up in crops grown with urine-derived fertilizers, the levels detected are extremely low. Concerns about their impact on health need to be calibrated with those over levels of trace contaminants associated with synthetic fertilizer products, biosolids, and other soil amendments. They should also address the impact of their manufacture or mining on the environment (Krista Wigginton, University of Michigan, Personal Communication, Sept 5, 2019).

¹² The Village Sanitation Pilot Study (VSPS) was funded by several Vermont foundations and involved an Eco- Americorps member for the 2018–2019 year. A partnership between the Rich Earth Institute and the Windham Regional Planning Commission, the team held community meetings in two villages (chosen after an application process that gauged broad community interest) to discuss options for wastewater manage-

ment, learn about ecological sanitation and to consider urine diversion as a nutrient management strategy. Community leaders then engaged their neighbors through interviews about their current wastewater systems and their concerns. Site visits were conducted by Nutrient Networks, a non-profit organization consulting to alternative sanitation projects, to determine retrofits for urine diverting systems in 23 homes and 3 public facilities. Sustainable waste management strategies would thus increase flexibility in land use planning.

¹³ Further resources on “liberating structures” can be found at <http://www.liberatingstructures.com/>.

Supplemental file

The supplemental file for this article can be found as follows:

- **Text SI.** Sample Focus Group and Interview Prompts. DOI: <https://doi.org/10.1525/elementa.408.s1>

Acknowledgements

We thank Phoebe Gooding, Chris Askew, and Malavika Sahai who helped conduct literature reviews, focus groups, surveys and interviews. Julia Cavicchi, an ECO-AmeriCorps service member at Rich Earth Institute, was closely involved in the revision process and assisted with literature review. We also acknowledge Linda Macpherson of New Water ReSources who designed an animation with The Rich Earth Institute that we deployed in focus groups and survey research to explore educational impacts. Finally, we are grateful to have received meticulous, critically astute and constructive comments from two anonymous reviewers as well as an Associate Editor from this journal, and wise guidance from the Editor in Chief.

Funding information

This research was funded by NSF INFEWS Grant 1639244 and conducted under IRB approval number HUM00116968.

Competing interests

Kim Nace is a Co-Director of Rich Earth Institute. Tatiana Schreiber is a Research Associate (social research) at Rich Earth Institute and a faculty member in the Environmental Studies Department at Keene State College. Although Rich Earth Institute advocates for UDF development and implementation, our overarching research design and specific methods were designed to prevent any skewing of results that might result from that.

Author contributions

- Contributed to conception and design: ALL
- Contributed to acquisition of data: TS, RH, ANP, SO
- Contributed to analysis and interpretation of data: ALL
- Drafted and/or revised the article: TS, RH, SO, KN, ANP
- Approved the submitted version for publication: ALL

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Interviews (These represent a sub-set of the 24 interviews conducted)

Massachusetts Agricultural Educator. (June 6, 2018). [Interview with Tatiana Schreiber, with Alex Sabido]. Amherst, Massachusetts.

Massachusetts Environmental Advocate. (August 3, 2017). [Interview with Tatiana Schreiber]. Greenfield, Massachusetts.

Massachusetts Wastewater Treatment Plant Operator. (August 15, 2017). [Interview with Tatiana Schreiber]. Springfield, Massachusetts.

Michigan Agricultural Educator. (February 26, 2019). [Interview with Rebecca Hardin, with Shaina Opperman]. Hillsdale, Michigan.

Michigan Environmental Advocate. (June 26, 2018). [Interview with Audrey Pallmeyer]. Higgins Lake, Michigan.

Michigan Wastewater Treatment Plant Operator. (February 19, 2019). [Interview with Rebecca Hardin, with Shaina Opperman]. Bay City, Michigan.

New Hampshire Soil Scientist. (June 26, 2018). [Interview with Tatiana Schreiber]. Keene, New Hampshire.

Vermont Planner. (June 27, 2018). [Interview with Tatiana Schreiber, with Alex Sabido]. Morristown, Vermont.

Focus Groups

General Public Focus Group 1. (August 14, 2017). [Facilitator, Audrey Pallmeyer, with Chris Askew-Merwin]. Ann Arbor, Michigan.

General Public Focus Group 2. (August 10, 2017). [Facilitator, Tatiana Schreiber, with Phoebe Gooding]. Brattleboro, Vermont.

General Public Focus Group 3. (November 14, 2017). [Facilitator, Tatiana Schreiber, with Phoebe Gooding]. Bellows Falls, Vermont.

Farmer Focus Group 1. (March 15, 2018). [Facilitator, Tatiana Schreiber, with Phoebe Gooding]. Brattleboro, Vermont.

Farmer Focus Group 2. (March 21, 2018). [Facilitator, Tatiana Schreiber, with Phoebe Gooding]. Brattleboro, Vermont.

How to cite this article: Schreiber, T, Opperman, S, Nace, K, Pallmeyer, AN, Love, N and Hardin, R. 2020. Leveraging integrative research for inclusive innovation: urine diversion and re-use in agriculture. *Elem Sci Anth*, 8: 12. DOI: <https://doi.org/10.1525/elementa.408>

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Knowledge Domain: Sustainability Transitions

Part of an *Elementa* Forum: Multi-Stakeholder Initiatives for Sustainable Supply Networks

Submitted: 31 October 2019 **Accepted:** 22 February 2020 **Published:** 24 March 2020

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