Understanding Pathways to Contaminant Exposure in North Carolina’s Community Gardens

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Abstract

Urban agriculture and community gardens can be a means to increase the wellbeing of vulnerable communities, including reductions in food insecurity, opportunities for outdoor exercise and social interaction and even increases property values (Folstad et al., 2015). Unfortunately, community gardeners may potentially be exposed to contaminants through contact with soil at garden sites or through pesticide usage. There are three major factors that can increase the potential for the presence of contaminants and for subsequent exposure: i) the site's history and surrounding land uses; ii) land management practices in the garden; and iii) community gardeners' behaviors and perceptions (US EPA, 2011a). Additionally, based on previous research in North Carolina by the Duke Superfund Research Center, community gardens at risk of having contaminated soils often overlap with areas with a higher-than-average percentage of low-income and minority populations. There are, however, a number of land use practices that may reduce the potential for exposure to contaminants. In addition, individual behaviors surrounding personal hygiene, food safety, use of protective equipment, and additional precautions may also reduce the potential for exposure (Folstad et al., 2015). Our study applied a mixed methods approach to understand the extent to which community gardeners currently employ the land use management practices and individual behaviors that reduce exposure, as well as the barriers to adoption of these behaviors. Our findings will inform future efforts on the part of the Duke University Superfund Research Center to collaborate with community gardeners to reduce the potential for contaminant exposure.

Key words: Community gardens, contaminant exposure, soil contaminants, pesticides, behavior change, North Carolina, individual behaviors, management choices

Significance of our Study

Community gardens are a valuable resource for promoting health and wellbeing, reducing poverty, growing community bonds and more. Yet gardens that are located on previously developed sites have a higher likelihood of soil contamination as a result of former land use, as well as current nearby pollution sources (US EPA, 2011a). While pollution and contamination are large and systemic problems, conscientious behaviors and management choices in these community gardens can help to safeguard community members from potential exposure to these health issues. (US
To reduce these potential health risks while maintaining the advantages associated with participating in a community garden, we need to first understand the extent of the issue, as well as the perspectives of the individuals involved. Therefore in this study we examine the potential sources of contaminant exposure at community gardens and the motivations and barriers influencing exposure-related behaviors of community gardeners. This research was conducted in conjunction with the Research Translation Core for the Duke University Superfund Research Center (DUSRC). Our work therefore lays the groundwork for the DUSRC to develop effective strategies to encourage beneficial behavior change, preventing potential contaminant exposures at community gardens in North Carolina and beyond.

**Introduction**

**Communities and the Environment**

Community gardens are defined as any public or private facility used by more than one person to cultivate edible or ornamental plants (Edmonds et al., 2013). For this case study, we consider the broad definition of “community garden” provided by the North Carolina Community Garden Partners (hereafter NCCGP), which defines them as any piece of land used for gardening by a group of people.

It is widely accepted that community gardens can bring multiple benefits, including the improvement of sustainable local food systems, better access to healthy food, inclusivity and sense of belonging for individuals (NCCGP, 2017; Schmelzkopf, 1995; Carney, et al., 2012). They can also provide benefits for the community such as economic development, youth education and skill development, open space use, crime prevention, leisure and recreation, neighborhood beautification, cultivation of social relationships, cultural expression and ultimately community empowerment (Draper and Freedman, 2010).

“Community gardens are as varied as the neighborhoods in which they thrive. Each is developed to meet the needs of the participants who come together on common ground to grow fruits, vegetables, flowers, herbs, and ornamental plants” (Bradley, 2007, p.1; Draper and Freedman,
Despite these many benefits, community gardens are often limited by available physical and human resources. Ideally a community garden location would be chosen based on consideration of factors such as soil and water conditions, distance from local residents, zoning, and land ownership for long-term availability (Edmonds et al., 2013). However, the establishment of a community garden is more often directly influenced by limited human and economic resources. This leads to a predominance of siting on lands that are considered to have little market value, or reliance on the presence of sponsor groups that may have available land, resources, or interested members (Schmelzkopf, 1995; NC State Cooperative Extension, n.d; Saldivar-Tanaka and Krasny, 2004). In addition to often facing insecure land tenure, community gardens also tend to have limited access to resources such as water, tools, soil and plant and building materials (Saldivar-Tanaka and Krasny, 2004; Wakefield, et al., 2007).

“Community gardens can be found at such diverse locations as schools, parks, housing projects, places of worship, vacant lots, and private properties” (Birky, 2009). There are many organizations and agencies, such as non-profit and government agencies, that commonly provide valuable support to community gardens. Some of the common identified types of support are advocacy, organization, land tenure, material/labor support, technical assistance, human resources, education and information. For instance, this organizations can provide material support including tools, plant materials, compost, soil, and construction supplies for a small price or for free (Saldivar-Tanaka and Krasny, 2004).

As a result of this diverse and varied nature of community gardens, it is important to consider how the environment of community gardens relates not only to location but also to work, health, recreation, housing, culture, and history in the community (Mascarenhas, 2009). We employ this holistic view in our study, analyzing not only physical location and land history but also the story and motivations of the garden and gardeners we are working with.

**Garden Typologies**

In working with community gardens, it is beneficial to understand that there are different types of
garden, each with unique properties, goals, and needs. Typologies of community gardens can be useful in this respect, but only to the extent that they categorize gardens according to relevant characteristics. For example, a typology that is helpful to this project must consider factors that influence likelihood of contaminant presence and exposure, whereas this might not be relevant in a typology designed to aid garden networking. Academic and organizational literature already exists on the subject, which was helpful in laying the groundwork for developing a typology from our research to provide to DUSRC for future use.

The North Carolina Cooperative Extension divides community gardens into five categories: plot gardens, cooperative gardens, youth gardens, entrepreneurial market gardens, and therapeutic gardens (NC State, n.d.). These designations separate gardens according to their structure and goals. A plot garden, for instance, is a community space that is divided into sections, each of which is allotted to an individual or family for their own use. On the other hand, a youth garden is designed to provide educational experiences for children and families, and is therefore divided into whatever sections are relevant for the desired curriculum.

A study by Ferris et al. (2001) describes a typology surrounding community gardens in San Francisco, California, dividing gardens into eight categories: “leisure gardens, child and school gardens, entrepreneurial gardens, crime diversion/work and training gardens, healing and therapy gardens, neighborhood ‘pocket parks,’ ecological restoration gardens, and demonstration gardens.” These categories have significant overlap with the North Carolina Cooperative Extension’s assessment, but are based almost entirely on the intent of the garden, and the authors emphasize that the garden types are not mutually exclusive.

Drake and Lawson (2015) focus entirely on garden structure by suggesting three categories: those having individual plots, those where all plots are shared and decisions are made collectively, and those that feature a combination of these two structures. The authors also examine how gardens may be categorized according to types of partner organizations, types of financial support, types of relevant management issues, and types of land ownership.

The North Carolina Community Garden Partners Gardens Directory also organizes gardens by many different characteristics depending on what the reader is most interested in. The main
typology has 12 categories related to what organization the garden is associated with, as seen in Figure 1 (NCCGP, 2017). In addition the directory allows the reader to sort by land ownership, number of plots, acreage, funding source, what they grow, who they serve, the primary culture of the participants, and more.

**Theoretical Framework**

The project’s research design is a descriptive case study (Yin, 1994). A case study is defined as "a research method that focuses on understanding the dynamics of a single setting" (Bryman, et al., 2004). In addition, a case study is bounded by the current context, and therefore space and time (Millis, et al., 2010). Our project is specifically a multiple case study because we are using multiple cases within the state of North Carolina to "reveal complementary aspects of the phenomenon" being studied (Bryman, et al., 2004). As part of the theoretical framework for our multiple case study, our project used research on public health behavior change, risk assessment, and social determinants of health that was relevant to community gardens in the US. At its heart, this is a public health study, and therefore we draw heavily from public health methods and theory. Here we outline the range of issues that could potentially affect community gardens and the safe growth of food, as well as methods for encouraging safe behaviors.

**Public Health and Behavior Change**

The CDC Foundation (2017) defines public health as “the science of protecting and improving the health of families and communities through promotion of healthy lifestyles, research for disease and injury prevention and detection and control of infectious diseases.” In seeking to promote individual and garden-level choices that reduce potential contaminant exposures that can harm health, our project draws much of its theoretical support specifically from health behavior change theory. This includes two models that are especially helpful: the health belief model (Rosenstock et al., 1988) and the social ecological model (Bronfenbrenner, 1994).

The health belief model states that a person’s likelihood of changing their behavior in response to a health threat depends on three factors: sufficient motivation or concern, a belief that the person is vulnerable to the threat, and the belief that following a recommendation will reduce the threat
Rosenstock et al., 1988). We apply this model by investigating whether people are concerned about contamination in their gardens, whether they are aware of health risks of contamination, and whether they are currently taking any precautions against contaminant exposure.

The social ecological model was originally developed by Bronfenbrenner (1994), and explains human social development in an ecological context. It emphasizes the many complex and interacting ways in which humans are impacted by their environment, and vice versa. Importantly, the environment’s impact on a person depends on that individual’s social and behavioral situation (Stoklos, 1996). This model influences our study by drawing attention to the ways that social and personal context affect a person’s relationship with contaminants. While a contaminants’ presence is important, individuals’ behaviors are what ultimately determine if and how much they are exposed to that contaminant.

These models tell us that health behavior change depends on more than just availability of information. While we want gardeners to have access to as much information as they would like, research suggests that simply educating them on the issues will not have much impact on their actual behavior (MacKenzie-Mohr, 2000). For this reason, we have taken a social marketing approach to understanding how we can encourage safe behaviors, which uses health behavior change theory as a foundation.

Community Based Social Marketing uses a combination of psychological principles and marketing strategy to encourage behavior change. This pragmatic approach involves identifying the benefits and barriers to behavior change, and developing a communications strategy tailored to the target audience based on these factors. The overall goal of this community-based strategy with regard to community gardens in North Carolina, should the DUSRC carry it out, is to implement a behavior change program across the state, and to evaluate its effectiveness (MacKenzie-Mohr, 2000; MacKenzie-Mohr and Smith, 1999).

Community-based social marketing depends upon establishing a detailed understanding of the population in question, as well as carefully crafting communication and positioning strategies (Lee and Kotler, 2014). Choosing a target audience, selecting a desired behavior to change, and positioning that behavior change in a relevant and compelling way all require foundational data.
about the population and issue (Lee and Kotler, 2014). A major goal of our study was to build this understanding, examining which garden behaviors would be most effective to change, and ways we can segment our audience to better tailor our messaging.

According to Grier and Bryant (2004), “the widespread adoption of social marketing in public health has garnered important successes.” This method allows us to intervene at a more useful level than simple education, without having to dictate what garden managers should require of their participants.

Our use of the community-based social marketing approach depends on our ability to establish a working relationship with community members. To do this, we draw on principles from community-based participatory research, which is described by Wallerstein and Duran (2013) as “an alternative research paradigm, which integrates education and social action to improve health and reduce health disparities.” By educating gardeners as we gather information from them, and by encouraging them to gather their own information on contamination, we seek to foster a relationship based on trust and empowerment.

**Human Health Risk Assessment**

**Hazard Identification.**

In this study, we define contaminants as any substance that is hazardous to human health. Soil contaminants such as heavy metals may occur in soils in a form that could be taken up by humans. This study also considers pesticides, which are defined as any substance used to treat animal or plant pests in a garden, including organic, natural, and synthetic products. Pesticides may be taken up by humans not only through soils but also through use and direct contact. Some of the main contaminants of concern in North Carolina community gardens include lead, cadmium, mercury, arsenic, zinc, copper, polycyclic aromatic hydrocarbons (PAHs), and chromium (Crozier et al., 2016; Jarup, 2003). For instance, studies in North Carolina have found that soil contamination caused by historical uses of arsenic - i.e. in pesticides and for wood treatment- can be further increased by current agricultural and industrial uses (Salido, 2003). However, while most of these are unlikely to occur in high enough concentrations to cause acute
symptoms, when an individual - especially a pregnant woman or a young child - has repeated exposure to them, they can cause long-term health problems ranging from birth defects to cancers (Kessler, 2013). Young children are considered particularly vulnerable to contaminant effects because environmental toxins can impact their development, meaning they “can leave a lasting signature on the genetic predispositions that affect emerging brain architecture and long-term health” (Shonkoff et al., 2012).

While it is possible to test soils for these contaminants, doing so can be costly and is outside the capacity of many community gardeners. It was also outside the scope of this study. Instead, we thoroughly examined the science behind contaminant sources and pathways of exposure, which allowed us to understand the factors that increase the likelihood that a garden has contamination and to evaluate the best practices for reducing exposure risk in gardens. Additionally, this strengthened our ability to communicate with gardeners about contaminant concerns even without access to test results, because while many community gardens may not have the resources to do robust soil testing for contaminants, all should be able to do cursory evaluations and adopt basic safety practices (Latimer et al., 2016).

Many sources of contamination arise from land uses near the garden or historical land uses at the garden site itself. Ideally, community garden founders should evaluate these potential contamination sources before deciding upon the location of a garden. However, lack of knowledge about contamination issues - combined with a lack of viable options for a garden site - often mean that potential for contamination is not taken into account. Such potential contaminant sources include roads with heavy traffic, lead-based paint, industrial or commercial sites, coal-fired power plants, and agricultural operations, construction debris (EPA, 2011a; Mitchell, et al., 2014; Weller Clarke, et al., 2015). Nearby brownfields, superfund sites, and landfills are also concerns (EPA, 2011a, Salido, 2003).

Other times, contamination can result from actions taken within the garden. Gardeners and managers may bring in potentially hazardous substances for use in garden structures, plant care, and other purposes. In these instances, contamination may arise from pesticides and herbicides, treated wood, building materials, and burning trash, as well as compost that has taken up
substances during its formation (Weller Clarke et al., 2015; Heiger-Bernays et al., 2009; Crozier et al., 2016). Arsenic and chromium may leach into soil if raised beds are made from treated wood manufactured before 2004, and burning trash or adding city compost may cause PAHs and dioxins to be deposited into the soil (Salido, 2003; Heiger-Bernays et al., 2009; Crozier et al., 2016). Although there are pesticides and herbicides that can be used safely, they can easily become dangerous as a result of misuse (Crozier et al., 2016).

**Exposure Assessment.**

Once contaminants have made their way into a community garden, there are a number of pathways by which they can enter the human body and cause harm. One means is through direct ingestion, which can occur when contaminated soil or pesticide residue are not cleaned off of produce before it is consumed, or when children intentionally or unintentionally ingest soil through play in the garden. This last is particularly troubling as children are more susceptible to health impacts from contaminant exposure (Shonkoff et al., 2012; ATSDR, 2013). Another means of ingestion is by consumption of crops that have taken up contaminants into its tissue (Defoe et al., 2014). Root crops are especially prone to contamination because they are physically exposed to the soil, followed by leafy vegetables, while fruit-bearing crops are for the most part less susceptible (Defoe et al., 2014). There are some notable cases where plants are more likely to take up contaminants; for instance, cabbages and mustard plants (Brassicaceae) are known to take up lead (Henry, 2000). Yet another is direct contact, which is primarily a concern for pesticides and other chemical products that may get onto a person’s skin while being handled or applied (Aktar et al., 2009).

A combination of garden management practices and individual gardening practices and harvest use may augment or reduce the potential for exposure to contaminants (Kim et al., 2014). By avoiding the use of treated wood (especially wood that was treated before 2003, at which time use of chromated copper arsenate was more prevalent), planting crops away from roads, assigning rules to the use of pesticides and other products, and following various other safety procedures, garden managers can reduce the chances of contaminants entering the soil (Heiger-Bernays et al., 2009; Weller Clarke et al., 2015; Crozier et al., 2016).
Individual gardener behavior also determines the potential for exposure. Exposure can be reduced by wearing protective equipment such as gloves, thoroughly washing their hands and clothing after gardening, and remove produce surface contaminants by for example washing and peeling (Kim et al., 2014). If there are concerns about specific areas of the garden - for instance, a plot that is near a source of lead paint - gardeners can selectively plant flowers and other inedible plants, rather than grow food in particularly contaminated soil. When children are present in the garden, adults should supervise them closely to ensure they do not consume potentially contaminated soil or other harmful substances.

**Developmental Impacts.**

While levels of contaminants in community gardens may vary, we are primarily interested in long-term exposures, which may result in significant health impacts even if doses are low (ATSDR, 2011). Our study particularly focuses on those groups of garden users that are especially susceptible to the impacts of exposure, including children and pregnant women.

Children are particularly susceptible to health impacts from nearly all contaminants. They are more likely to suffer developmental problems as a result of contaminant exposure, and are especially vulnerable to lead and arsenic, some of our primary contaminants of concern (Chance, 2001). Among these primary contaminants of concern, the predominant health effects empirically linked to exposure in children include neurobehavioral changes, endocrine disruption, decreased immune function, and higher rates of childhood cancers (Chance, 2001). Additionally, because of the rapid changes in development occurring in early childhood, doses may produce radically different responses in children of different ages (Faustman, et al. 2000). For this reason, even levels of contamination that are considered safe for adults may be unacceptable for children. Faustman et al. (2000) also point out that children are more likely to “explore” their environment, coming into more frequent contact with potential sources of contamination. The health of children can also be influenced prenatally by the pregnant mother’s exposure to contaminants (Chance 2001). Contaminants and other environmental factors may impact gene expression, epigenetics, and hormone signals, and may be transmitted to a fetus through the placenta or to a newborn through lactation (Silveira et al., 2007).
Beyond soil contaminants, pesticides can pose a threat to the health of children through neurotoxicity (Faustman et al., 2000). Pesticides have been shown to pose health risks for humans of all ages, especially as endocrine disruptors (Aktar et al., 2009). Exposures are particularly high for individuals who work directly with the pesticides, but Aktar et al. (2009) report that “No segment of the population is completely protected against exposure to pesticides and the potentially serious health effects (p.3).”

**Social Determinants of Health**

In studying how contaminants may affect community gardeners, we are particularly concerned about health impacts on those individuals who are food insecure or socioeconomically disadvantaged. Health disparities of this sort must be attributed not only to individual health behaviors, but also to macro-level social and environmental factors (Brulle & Pellow, 2006).

The desire to improve access to affordable fresh fruits and vegetables in urban food deserts, as well as the drive to improve the public image of troubled neighborhoods, has caused community gardens to be disproportionately located in these neighborhoods (Defoe et al., 2014). Adopting urban agriculture and community gardens is part of the development of sustainable food systems - it can be a powerful strategy to fight food insecurity in vulnerable communities and even increase property values in a neighborhood (Folstad et al., 2015). However, for populations already vulnerable because of health disparities and exposure to other environmental contaminants, exposure to contaminants through community gardens can add additional burdens to already strained health.

The unequal distribution of environmental conditions, such as the location of food deserts or unhealthy food environments, have been found to increase the rates of morbidity, mortality and adverse health outcomes (Walker et al., 2010; Gordon et al., 2011). These disparities are commonly associated with factors such as residential segregation, poverty and neighborhood deprivation (Walker et al., 2010). In addition to racial/ethnic and socioeconomic disparities found to affect the existence of food deserts and unhealthy food environments, there are also factors within the built environment, such as the proximity to healthy food outlets, that can affect health disparities in neighborhoods (Walker et al., 2010).
There is always a possibility that “social and environmental risks may combine to create synergistic or cumulative burdens on the health of the most vulnerable populations” (Brulle & Pellow, 2006). For this reason, strategies to address factors that may increase adverse health outcomes in a community - such as food insecurity - must also take into account environmental factors that may have implications for public health. Additionally, we must consider specifically which vulnerable populations are being affected by the environmental harms inherent in contamination. For instance, we are particularly concerned about the effects of contaminants on children, which may be amplified if that child is undernourished, as in the case of lead (WHO 2016). In selecting which gardens to work with in this project, we analyzed data from EJScreen (2016) to evaluate which areas had high concentrations of potentially vulnerable populations: minorities, children under 5 years old, adults over 64 years old, linguistically isolated populations, and low income households.

**Research Goals and Strategy**

This study was conducted as part of a pilot study designed by the Duke Superfund Research Center to help initiate their Community Garden Project. The purpose of the Community Garden Project is to study the effects of contaminant exposure in community gardens on early life, particularly in North Carolina by analyzing current and legacy contamination of soils, as well as direct human contact with contaminants through gardening activities such as working in and around pesticides. Our pilot study worked closely with six “focal” community gardens - as well as additional gardeners across the state - initially to answer three primary research questions:

- What types of land use and management choices exist that might lead to the presence of soil contaminants and pesticides in community gardens?

- What behaviors of community gardeners are present that might lead to exposure to soil contaminants and pesticides?

- What are the primary barriers to and motivations for changing those behaviors?

As our study progressed, it became clear that we also needed to answer a fourth research question, in order to offer more specific recommendations for the DUSRC social marketing
campaign:

- What are the most commonly used and trusted modes of accessing and dispersing information on soil contaminant and pesticide topics?

We took a mixed methods approach to this research in order to access a diversity of information from different perspectives. In doing so, we were able to harness both the subtlety of qualitative analysis, and the power of generalization derived from quantitative data from a survey of a considerably larger sample size. The survey was distributed to community gardeners across North Carolina, while the other methods were centered around six case study gardens, which we selected based on their likelihood to be representative of gardens statewide. Additionally, we conducted a review of the relevant literature, allowing us to situate our research in the current context of social health determinants and health risk assessment theory.

The pragmatic objective of this Master’s Project was to provide a broad characterization of the behaviors that might lead to contaminant exposure in North Carolina community gardens in order to inform the DUSRC’s project action plan moving forward. The variables we explored in doing so included the types of potential contaminant sources present at a given garden, the demographic background of garden participants, the level of knowledge and concern among gardeners, current individual and management practices, and barriers and motivations regarding behavior change. The specific products that we will deliver based on our Master’s Project research include:

- A strategy document to guide the development and implementation of a social marketing campaign to reduce exposure risk. This will include a characterization the relevant “market segments” we believe should be targeted by such a campaign and the best way to conduct outreach for each.
- An executive summary of our research and our findings to be shared, along with our full MP, with our organizational partners.
- Video recording of our final MP presentation and of an educational presentation on soil and pesticide contamination targeted to community gardeners. Both will be posted to the DURSC website and shared with our organizational partners.
Tradition of Inquiry

This study uses mixed methods, meaning that it collects data through multiple avenues, both qualitative and quantitative (Johnson et al., 2007). The primary benefit of using mixed methods in the social sciences is that researchers can use multiple data sources to perform what is called triangulation, a comparison of respondents’ answers to similar questions asked through different methods, which accounts for potentially biased effects of certain methods, and ensures validity (Johnson et al., 2007).

As such, a portion of this project is designed as a descriptive case study (Yin, 1994). According to Lewis-Beck et al. (2004), a case study is defined as "a research method that focuses on understanding the dynamics of a single setting.” In addition, a case study is bounded by the current context, meaning it is constrained in space and time (Millis et al., 2010). Specifically, our project is a multiple case study because we are using multiple cases within the state of North Carolina to "reveal complementary aspects of the phenomenon" being studied (Lewis-Beck et al., 2004).

Throughout the project we worked with six case study gardens across North Carolina. In studying these six gardens, we were able to analyze how gardeners are becoming exposed - and contributing to the exposure of others - to dangerous contaminants. While using multiple cases removes some of the depth and storytelling of the case study, it adds value in allowing us to find a more generalizable understanding of what issues are most relevant and generalizable to all community gardens in the state. This will be an invaluable foundation for the future work that our client, the Duke Superfund Research Center, will do to work with gardens and reduce exposures. We started our case study with a basis in the existing research on toxicology in community gardens, and a solid understanding of associated possible health problems. We conducted the study for a 6-month period between October 2016 and March 2017.

The remaining portion of this study takes the form of a web survey. Web surveys have been employed in social science research since the mid-1990s, when internet browsers were first being developed and successfully utilized (Couper and Miller, 2008). They are a newer mode of distribution for the social science survey, and have been shown to have comparable validity in their measures (Lonsdale et al., 2006). We designed and carried out an original web survey, which
was in distribution throughout January and February of 2017.

Sample Design

For our case study research, we selected six focal community gardens across North Carolina based on demographic criteria as well as the potential for environmental contamination. The gardens also were selected based on their accessibility and ability to collaborate on the part of the gardeners. Much of the information used to select these gardens was drawn from the NCCGP database. For the web survey, we attempted to reach as many community gardeners in North Carolina as possible, distributing the survey through email listservs and personal contacts.

North Carolina Community Garden Partners Database

The NCCGP website is home to a publicly accessible database containing information about all community gardens that have registered with the organization (NCCGP, 2017). According to its website, NCCGP is “a volunteer-based grassroots non-profit organization dedicated to increasing the quantity, quality and sustainability of community gardens across North Carolina” (NCCGP, 2017). This organization allows community gardens, as well as individual gardeners, to join its network, encouraging managers to register their gardens and become part of the online directory, or database. NCCGP actively seeks out new member gardens through its website, annual meeting, workshops, and newsletter (D. Boekelheide, personal communication, March 24, 2017). This means that although the organization makes efforts to reach out to community gardens, these efforts are not necessarily comprehensive, and the ultimate decision to register a garden with the database lies with gardeners themselves.

At the time of this document’s publication, there are 242 community gardens registered to the NCCGP database. The approximate geographic distribution of these gardens is shown in Figure 1. NCCGP organizes its database into twelve categories of garden type (where a single garden can be classified as multiple types): neighborhood gardens (66%), faith-based gardens (41%), community-school gardens (33%), food bank gardens (23%), and school gardens (27%). Beyond this categorization, the site also allows gardens to provide information about their founding date, geographic location, participant count, associated organization, plot count, size, types of
production, target audience and groups served, and funding source (NCCGP, 2017). However, none of these information fields are mandatory when gardens register on the website, so many gardens in the database contain only a portion of this information.

Case Study Garden Sample Selection

Throughout our study, we worked with six case study gardens. We attempted to select gardens that would present a representative sample of gardens across the state, based on the information that was accessible to us through the DUSRC’s pre-existing database and other online resources. We conducted interviews and observations with all six of these gardens, and additionally conducted focus groups and material culture analysis with three of them.

To select the six case study gardens, we used an existing database provided by the DUSRC Community Garden Project. This database included information about all gardens registered with NCCGP, including location, garden size, and estimated number of participants. It also assigned rankings of potential contamination susceptibility based on a combination of environmental justice indicators and proximity to potential contamination sources. These indicators included:

- Proximity to landfills
- Toxic Release Inventory sites
- National Priority List sites
- Treatment Storage and Disposal Facilities
- Brownfields
- Primary roads
- EJScreen scores for lead exposure (% housing stock built prior to 1973)
- Percent of minority and low-income residents per census block
- Percent of children under 5 years old per census block

The dataset was limited by the fact that it did not incorporate data on pesticide use, actual contaminant measurements, and the fate and transport of contaminants.

Initially, we narrowed down the list of potential case study gardens to those located within 150 minutes of driving time from the Duke campus in Durham, North Carolina. We also excluded
gardens that were categorized by NCCGP as being connected to schools, because the special vulnerability of children in social science research contexts makes the process of involving them in studies difficult. We then arranged the remaining gardens in order of highest likelihood of contamination susceptibility.

We examined the 30 most susceptible gardens more thoroughly, evaluating their proximity to different types of contamination source, along with other qualitative variables, including the primary users and functions of the garden. We selected six of these gardens, which we believed would offer a range of risk factors, user demographics, and garden characteristics. Additionally, we selected six “backup” gardens, in case working with any of the first six was not possible.

To initiate contact with each of our top six gardens, we emailed the person listed as the contact for that garden. We then followed up with phone calls where possible, and explained our project to the garden managers. One of our top gardens turned out to be too small to work with; another did not respond to our communications; another two proved unable to conduct a focus group. We contacted our “backup” gardens as needed, and engaged with a total of six case study gardens for the project.

**Survey Distribution**

The survey was distributed at a wider, statewide scale. It solicited responses from as many community gardeners in North Carolina as possible, not just from participants of the case study gardens. Notably, one particular garden manager did distribute the survey directly to their gardeners, increasing the proportional response rate of that garden. We accounted for this when conducting our statistical analysis. We distributed the survey through several email lists for community gardeners in North Carolina, which included the NCCGP, North Carolina Agricultural Extension offices, Resourceful Communities, and Local Food Policy listservs. After contacting the people in charge of each email list, describing our research, and receiving their agreement to distribute the survey, we sent them our drafted message that included the survey hyperlink. We asked them to forward this message to everyone on their email list. The message also included information about our research, and what the survey would entail, so that each person who received the email would have sufficient information. After approximately two
weeks, we requested that these email list managers distribute a follow-up email to remind gardeners to take the survey. We provided drafted text for this message. After allowing several days for gardeners to receive and view this follow-up email (and after observing a drop-off in survey response frequency), we closed the survey.

At the time of this document’s publication, there are 238 community gardens registered to the NCCGP database. This list of registered gardens is not exhaustive, and unfortunately it is difficult to know how many community gardens exist in the state that are not registered with NCCGP. It is also difficult to estimate the total number of participants at each garden, since detailed, accessible records are not often kept, and actual participation rates fluctuate significantly depending on season and local conditions. With these caveats in mind, we estimate that our population consists of roughly 3,000 community gardeners in North Carolina.

Because our estimated population size is 3,000 gardeners, we sought to gather at least 150 responses. This would allow us to describe our data with a 90% confidence level and a 6.5% margin of error, according to the formula $\text{Sample Size} = \frac{(Z\text{-score})^2 * \text{StdDev}^2(1-\text{StdDev})}{(\text{margin of error})^2}$ (Smith, 2013).

**Methods**

**Data Collection**

We employed five data collection methods within this study: key actor interviews, focus groups, garden observations, material culture analysis, and a survey. In combination, these methods allowed us to access a diversity of information from different perspectives, and to gain both depth and breadth of understanding. Furthermore, the use of multiple methods made it possible for us to triangulate results, increasing the reliability and validity of our findings as explained by Golafshani (2003).

**Key Actor Interview Procedure.**

Key actor interviews allowed us to hear about each case study garden in detail from a few highly knowledgeable individuals. The research team developed an interview guide based on our
research questions, anticipating what the garden managers would and would not be likely to know. This guide was iteratively reviewed to ensure it met our data goals without causing alarm or distress to the interviewees.

We conducted a total of nine interviews, six of which were with garden managers, and three of which were with non-manager garden participants. Our first interview at each garden was always with the official manager, and during that interview we asked for recommendations on a second person to interview. This constituted a limited version of the method known as snowball sampling, which strengthened our understanding of social dynamics within the gardens (Noy, 2008). When given options, we tended to choose the gardener who had been with the garden for the longest time.

One of our interviews was conducted in person, and five were conducted over the phone. On average, each interview lasted approximately one hour.

**Conducting the Interview.**

We began each interview with a brief description of the project, and an explanation of the consent form that grants us permission to audio record the interview. Once the interviewee agreed to the terms and completed this form, we began asking questions according to the interview guide. The topics of these sets of questions were, in order: the history of the garden and its land, the goals of the garden as an institution, the interviewee’s preferred sources of gardening information, the garden’s pest control practices, the interviewee’s concerns about potential soil contamination, and how the garden managers communicate to participants.

We followed our interview guide, allowing for relevant improvisations such as follow-up questions or modification of question order, as was appropriate given the interviewee’s answers. This method allowed for us to elicit insights that were new, both for the researchers and for the community gardeners, as explained in MacDonald et al. (2013).

At the end of the interview we thanked the participant for their time, and asked if there were any additional garden materials, such as flyers, newsletters, or applications, that they would be willing to share with us. Within a few days, we followed up via email to emphasize our gratitude,
and offer to provide any resources the garden may be interested in.

Over the next few weeks, we transcribed the audio recordings of these interviews in a denaturalistic way, omitting stutters, pauses, and filler words in order to most efficiently convey the speaker’s meaning for analysis (Oliver et al., 2005).

Focus Group Procedure.

Focus groups allowed us to observe how gardeners interact with each other, to hear multiple perspectives at one time, and to encourage participants to talk with each other and build off mutual knowledge. These processes helped us understand the group’s background knowledge, attitudes, priorities, and practices, as described in Kitzinger (1995).

Focus groups also provided a setting for us to share our knowledge with our case study gardens, as a way of thanking them for participating, and ensuring they had the knowledge and resources to deal with any concerns that might have arisen due to the potentially worrisome nature of our soil contamination research.

In developing our focus group guide, we considered multiple ways of eliciting information about gardeners’ current practices, as well as the benefits and barriers they perceived in relation to adopting safety behaviors, which included soil testing, building raised beds, and washing their hands after gardening. We planned the focus group to maximize gardeners’ ability to respond candidly to various questions about gardening while maintaining a positive atmosphere.

To recruit focus group participants, we asked the garden manager (with whom we had already made contact) to email gardeners and invite them to the event. Our goal was to have between eight and twelve gardeners, though this was only the case in one focus group; the other two had over twenty participants. This was a direct result of the manager’s own recruitment efforts, and interestingly, the number of focus group participants was largely proportional to the number of gardeners associated with each community garden. We believe this indicates that our groups were highly representative of the gardens.
Conducting the Focus Group.

We conducted a total of three focus groups - one per case study garden. We began each focus group with a brief description of the project, and an introduction of the researchers and their backgrounds. We followed with an explanation of the consent form that grants us permission to audio record the session. Once the participants agreed to the terms and completed this form, we offered them refreshments and gave them time to return to their seats.

Next we gave a brief presentation, which included a slideshow. This presentation explained what we meant by the phrase “soil contamination,” giving examples of potentially harmful contaminants and where they might come from. The presenter emphasized that these were contaminants that could be present in any garden, and that they were not necessarily relevant to that particular garden.

Throughout the presentation we paused to allow discussion, asking participants if they could think of any other potential sources of contamination, what they already knew about the topic, and whether any of the potential sources seemed relevant to their garden.

The slideshow concluded with a list of external resources that participants could find online. This list was mirrored in the printed factsheet that we then distributed to each member of the group, ensuring they knew where to find more information once the focus group was over.

Following the presentation, we asked members of the group to introduce themselves, and briefly describe their previous experience with community gardens, or gardening in general. This allowed us to understand the sources from which participants were drawing their knowledge of soil contamination and garden safety practices.

Once introductions were completed, we asked that four to six volunteers step forward for an activity. These volunteers were guided to a table that displayed two bins filled with dirty potatoes, two bins filled with clean water, several dish scrubbers, hand towels, and vinyl gloves. Volunteers were asked to divide themselves into two teams, each of which would have five minutes to get their potatoes as clean as possible given the tools provided. One of the researchers set a timer, and instructed volunteers to begin cleaning.
During this time, some of the focus group participants who did not volunteer for the activity stepped up to watch the competition; others talked amongst themselves. After the five minutes had passed, the volunteers were offered hand sanitizer, and directed to sinks with soap and paper towels in case they wanted to wash their hands. All focus group participants then returned to their seats, and we displayed the washed potatoes for the entire group to informally evaluate.

This facilitated a transition into discussion. We asked the participants what they thought about the activity, and whether they were in the habit of cleaning produce from the garden before eating it. We asked how they tended to prepare their produce, and more generally how they clean their hands, clothes, and tools after working in the garden. We discussed the use of pesticides and other addictive substances, and asked if gardeners had any concerns about soil contamination in their area. When the conversation drifted off topic, we politely guided it back to the question at hand. We also provided time for gardeners to ask us questions.

At the conclusion of the focus group we thanked everyone for their participation, cleaned up the supplies from the activity, and reminded gardeners that they could find our contact information on the fact sheet we had provided.

In the following weeks we transcribed the focus group recordings using a thematic transcription method based on our analytical node structure (see Figure 2). Thematic analysis allows for more rapid transcription, since not every word needs to be recorded, but maintains a relevant level of detail (Braun & Clarke, 2006).

**Observation Procedure.**

We conducted a total of six observations - one per case study garden. These observations allowed us to gain more detailed information about the location, size, and layout of the garden. They also allowed us to analyze in greater depth the potential sources of contamination present in each garden (Crozier et al., 2016).

During each observation, we met with the garden manager in person at the garden. If the manager had not yet completed a consent form allowing us to record the discussion, we provided and explained the form at this time. We also provided a photo release form, which granted us
permission to photograph the garden property. Once the forms were completed and the recording begun, we asked the manager to give us an informal tour of the garden.

Generally managers did not need much prompting, and showed us the raised beds, water sources, tool supplies, and other major garden features. We discussed where each type of plant was located, as well as what types of pesticides, compost, and other inputs were used. Other topics frequently included land use history, how the garden acquired the land, and how participants typically use the garden. We asked additional questions when they were relevant to our research goals.

During the observation, we used a checklist to take notes of our observations. This checklist addressed the size of the garden plots, proximity to potential contamination sources such as busy roads, types of structures present on the land, and types of tools and materials present.

We also photographed the garden, paying special attention to features like raised beds, compost bins, rainwater collection systems, and posted signage. During two of the three observations, no gardeners were present. In one observation, we made notes of the gardeners that were present, and what they were doing while we were there.

The garden observations generally lasted 30 to 45 minutes. After they were concluded, we compiled our notes and photographs from the visit, and over the next few weeks we transcribed the audio recording of the garden observations in the same naturalistic method as the interviews.

**Material Culture.**

In addition to analyzing information directly from garden managers and participants, we gathered items of material culture - both digital and physical - to expand our understanding of garden dynamics. Material culture is defined by Prown (1982) as “the study through artifacts of the beliefs - values, ideas, attitudes, and assumptions - of a particular community or society at a given time.” In this study, these items served to corroborate and expand claims made by gardeners, as well as yield insights into the structure and operations of the garden.

More specifically, we were interested in learning how managers communicate to garden
participants, what topics are considered important in their communications, and how many people engaged with garden content. We examined online materials including case study garden websites, social media sites, and websites dedicated to organizations associated with the case study gardens. We also collected print materials like maps and pamphlets where available, and requested that garden managers forward us a sample of electronic newsletters, emails, and other relevant materials.

These items were particularly helpful because the timeline of our project did not match up well with the growing season, meaning that there was not much gardening activity going on during our observations. Viewing photographs and content from the past year gave us an impression of what the gardens are like during the warmer months, when activity is generally much higher.

After collecting these items, the printed ones were scanned, and the digital ones were converted to image files, so that each could be imported to NVivo.

Survey Procedure.

We conducted an online survey of community gardeners, which allowed us to collect data that represent a diversity of garden types and gardener perspectives across the state. According to Baruch and Holtom (2008), surveys “can provide insight into individual perceptions and attitudes as well as organizational policies and practices.” These are exactly the goals we hoped to achieve; we wanted to learn how much individual gardeners know about soil contamination, and also what practices are common at their gardens.

Online surveys enable rapid data collection, which was appropriate for the short timeline of this project, and they also provide close control over the survey content and dynamics (Couper & Miller, 2009). This allowed us to present different sets of questions to respondents, depending on their answers to previous questions. We used this ability to customize survey questions based on whether the respondent was a garden manager or a garden participant, since each of these roles involves different sets of knowledge and experience.

We designed the survey by iteratively creating and evaluating questions as a team. We composed questions that we hoped would achieve our research goals, and edited them to maximize their
clarity and simplicity. Once roughly designed, we pre-tested our survey via expert review and a small pilot test. For the expert review, we solicited feedback from two personal contacts who have extensive knowledge of and experience with community gardening. For the pilot test, we distributed the survey to six community gardeners associated with Duke University and two additional Durham gardening organizations.

The expert review allowed us to ensure comprehension of our survey, meaning that respondents understood the questions in the way we intended them (Collins, 2001). It also allowed us to verify that the survey text provided sufficient context to facilitate information retrieval, wherein respondents are able to accurately remember the relevant experiences in their gardens (Collins, 2001).

The pilot test confirmed that the online survey did not have any technical difficulties, and that data were recorded fully. It allowed us to ensure there were sufficient response options for each question, and that the formatting was appropriate for the content present.

Data Analysis

Qualitative Analysis.

All data from interviews, focus groups, material culture, and observations were imported into NVivo, a qualitative data analysis software, for analysis and coding. We examined community garden users at specific community gardens in North Carolina as our units of study. Relevant background literature was used in combination with our research questions to create a strong node structure to look for relevant themes on the data collected at the gardens.

The nodes were directly related to our research questions; the first level of the hierarchy includes general topics that deal with behaviors, barriers, and potential sources of contamination, while the second level includes specific results we are interested in evaluating. Examples of these specific results include whether or not gardeners wash their hands, if gardens had raised beds, and if managers had conducted soil testing. For a more detailed view of our basic node structure, see Figure 2. For our comprehensive node structure, see Appendix C.
Prior to analyzing the observation and material culture data, we took steps to establish a dependable intercoder agreement (Lombard, et al., 2002). This intercoder reliability process included an initial meeting where the researchers coded for the same picture, article, and piece of observation checklist together, and discussed why a certain piece of information needed to be coded for a specific node. After this initial meeting, we reached a general agreement for how to capture questions, how we will create new nodes, rules for how and when we will run queries, delegated tasks, etc. We then proceeded to code separately. However, we held frequent meetings to evaluate the extent to which we made similar decisions in identifying and coding for relevant themes.

For the interviews and focus groups, we did more extensive concurrent coding practice and comparison. The researchers each began by coding an interview separately. As we coded, we found the structure required additional nodes to effectively capture what we were asking in the interviews, and that there were some similarities between our interview findings and our previous literature review and materials analysis.

When we had completed the initial coding, we agreed on new nodes and their meanings, and merged some coding. We then ran a coding comparison query. This query, while it showed that we had 90% or more agreement on most nodes (and no more than 3% disagreement in most cases), the alpha often showed that our coding could have easily been by chance. We performed the same tests on a focus group recording, and adjusted the node structure accordingly.

**Survey Analysis.**

To analyze the survey, all results were downloaded in a CSV file from the Qualtrics website. We prepared these data for analysis by removing all responses that were not at least 50% complete. The majority of incomplete responses appeared to have been recorded when people opened the survey on their computer, but failed to continue past the first page.

We began by performing a wide variety of basic calculations in Microsoft Excel, including the mean, median, mode, and range of variables of interest. These allowed us to address some of our fundamental research questions, as well as understand the demographics of our sample.
The results were then imported into the statistical software Stata, where we ran regressions on the quantitative data. These analyses allowed us to investigate which factors influenced gardener knowledge, concerns, and preferred information sources.

To begin, we separated manager and non-manager responses, since these groups were asked separate sets of questions. We then visualized the data using plots, evaluated correlations between variables, and tested their distributions. Next we tested each set of data to ensure that it met the assumptions of our ordered logistic regressions. In order to comply with the independence assumption, we clustered gardeners’ responses for a high response garden for which around 10% of the total respondents were participants. We also ensured that there was no high correlation between our independent variables. Finally, we tested for the proportional odds assumption for all our regressions. Ordered logistic regressions assume that the relationship between each pair of outcome groups is the same. We performed nine regressions in total.

Sources of Error

In all of our data collection, there is the potential for selection biases. Firstly, our case study gardens were drawn from the list of gardens registered with NCCGP, which likely excludes some gardens within our geographical range of interest. This list is in the form of an online directory which categorizes gardens according to their “type,” which generally refers to the nature of the garden’s supporting organization. This list relies on gardens to identify themselves or other partners in the area. Given the limited resources available, we were largely unable to consider gardens that are unregistered with NCCGP, or are in some other way not classified under this definition. It is possible that such gardens could have significance to our research, but given the timeline of this study, we must simply acknowledge this limitation, and use care in generalizing our findings.

Secondly, the fact that some of the gardens we contacted did not respond to our communications or were otherwise not able to participate suggests that our sample is skewed toward more organized gardens. Thirdly, when we selected our case study gardens, we gave extra weight to
the ones with which we already had contact, as this would improve the likelihood that they would be willing to participate in our project.

Because our survey was conducted online, it excluded respondents who did not have access to a computer or internet. If this research is ever revisited, we highly recommend distributing a paper version of the survey as a supplement. Another potential source of error with the survey is non-response bias, which occurs when the respondents are different from the people who received the survey email but failed to take it (Whitehead, 1993). In this case, for example, it is possible that individuals who were particularly concerned about soil contamination issues were more likely to take the survey than those who did not have much concern.

In the interviews, the primary source of potential error would be social desirability bias, which occurs when a respondent answers potentially sensitive questions in a manner that he or she perceives to be preferable in the eyes of the researchers (Podsakoff, 2012). In the context of this research, this would likely involve a respondent thinking we preferred gardens that did not use chemical pesticides, that had tested their soils, that had large numbers of participants, and so on. To avoid this bias, we made efforts to position ourselves as gardeners, emphasizing that we had experienced the difficulties of dealing with pests, expenses, and logistics of gardening. When possible, we also indicated that we had learned of gardens that take a wide variety of approaches, implying that many forms of garden management and individual behavior are socially acceptable.

Much of this similarly applies to the focus groups. Although there is a potential for the social dynamics in a focus group to influence participants’ responses to some questions, we took steps to minimize and address the risk of gathering inaccurate information (Robinson, 1999). First, we maintained a positive atmosphere and emphasized the confidentiality of the group’s discussion. Second, we conducted a gamified activity to establish shared concepts and to directly elicit personal feelings about the subject matter. Finally, we triangulated the focus group analysis with data from interviews, material culture, and observations at each garden. This allowed us to assess the reliability and validity of focus group statements (Golafshani, 2003).

Our observations may have been skewed in some respects by the fact that we visited the gardens
outside the growing season. For instance, it is possible that we found fewer tools, products, and plants than we would have during the spring, summer, and fall months. We have taken this into account, and therefore focus most of our observation analysis on garden features that do not change seasonally, such as the layout of raised beds, the presence of signage, and the garden’s position relative to potential contaminant sources.

It is possible that the content of our material culture items is biased toward “positive” portrayals of the gardens, especially since some of these items are used to promote the garden to prospective participants. However, this does not impede our ability to use material culture as a way to understand communication methods and garden norms.

Based on some of the write-in results we received on the survey, it appears some respondents drew inaccurate conclusions about our motivations. For instance, one person expressed concern that we were an activist group attempting to ban pesticides, while another was offended by our question on race. While these are outliers, it is possible that some of the respondents modified their answers based on their perceptions of our research intent.

**Ethical Considerations**

Although our study did not involve any direct risks to participants, it did deal with a topic that has the potential to cause a sense of fear and helplessness, or to drive participants away from their community gardens. For this reason, we took extra care to follow appropriate research ethics, and to empower the communities we worked with.

As Smith and Blumenthal (2012) explain, ethical community research depends on “community engagement, mutual learning […] and commitment to sustainability.” In our study, we have engaged the communities surrounding our case study gardens by involving as many members as possible (through focus groups) and making the project relevant to their needs (by adapting our focus groups and interviews each time we learn more about the community).

We engaged in mutual learning by offering our own informational resources while inviting information from the gardeners themselves. At every opportunity, we offered to provide additional resources for gardeners. We also emphasized the sustainability of our efforts by
reporting back to the communities with the results of our study, and by striving to build relationships that will be productive for years, both for the DUSRC and the gardeners.

More broadly, social science research depends on three ethical principles: autonomy, justice, and beneficence (Orb et al., 2000, United States, 1978). We respected autonomy by asking for consent before conducting and recording interviews, garden observations, and focus groups, as well as before respondents took the survey. While some of these consent texts were lengthy, due to the requirements of our Institutional Review Board, we made efforts to use easily understandable language, and highlight the portions of the consent agreements that would be most relevant to participants.

We respected justice by recognizing that some of our study participants were vulnerable in the sense that they susceptible to contaminant exposure, and we made efforts to avoid burdening them, including working around their schedules, providing meals during focus groups, and allowing them to guide discussions when appropriate.

Finally, we respected beneficence by protecting gardeners’ identities through rigorous anonymity protocols, as well as using the results of our research in a way that benefits the gardeners who participated. Directly, we distributed a summary sheet of the results of our study to the gardeners who helped us, allowing them to learn what some of the most common barriers to exposure reduction are. Additionally, our research is designed to contribute to an informational campaign that will encourage adoption of safety behaviors among gardeners, hopefully reducing contaminant exposures among these individuals.

Sample Description

North Carolina Community Gardens

Gardens are abundant throughout North Carolina in both urban and rural landscapes, but they are more common in highly populated areas (NCCGP, 2017). For the most part, these gardens are relatively small; of the gardens in the NCCGP directory, the majority are less than 1 acre (86% of gardens) with about 46% less than ¼ acre. They range in management style and supporting organizations from faith-based to school gardens, but the majority of registered community
gardens (66%) consider themselves to be neighborhood or public gardens (NCCGP, 2017). The vast majority of these gardens were formed after the year 2000, and roughly 15% of all currently registered gardens were formed in 2015 or later (NCCGP, 2017).

**Description of our Six Case Study Gardens**

We begin describing our results by providing some basic information about each of our case study gardens. To protect the anonymity of these gardens and the respondents within them, we have created pseudonyms for each community garden based on simple distinctions. We refer to the gardens as County Garden, Church Garden, Refugee Garden, Medical Garden, School Garden, and City Garden. See Table 1 for a guide to these gardens.

<table>
<thead>
<tr>
<th>Name</th>
<th>Established</th>
<th>Size</th>
<th>Goals</th>
<th>Location</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>County</td>
<td>1997</td>
<td>1 acre</td>
<td>Food donation, personal gardening</td>
<td>Exurban</td>
<td>Local families</td>
</tr>
<tr>
<td>Church</td>
<td>2010</td>
<td>1 acre</td>
<td>Personal gardening</td>
<td>Suburban</td>
<td>Local families, volunteer groups</td>
</tr>
<tr>
<td>Refugee</td>
<td>2015</td>
<td>¼ acre</td>
<td>Sustenance, community engagement</td>
<td>Suburban</td>
<td>Refugee families</td>
</tr>
<tr>
<td>Medical</td>
<td>2010</td>
<td>¼ acre</td>
<td>Food donation, health, education</td>
<td>Suburban</td>
<td>Clinic patients, volunteer groups</td>
</tr>
<tr>
<td>School</td>
<td>2013</td>
<td>1 acre</td>
<td>Education, community engagement</td>
<td>Suburban</td>
<td>Young students, local residents</td>
</tr>
<tr>
<td>City</td>
<td>2009</td>
<td>¼ acre</td>
<td>Food donation, community engagement</td>
<td>Urban</td>
<td>Local families</td>
</tr>
</tbody>
</table>
All our case study gardens were in somewhat developed areas; four were located in suburbs, one was located in a more urban area (although not as developed as the heart of a large city), and one was in an exurban area, meaning that it was somewhere between suburbs and a more rural area, with some buildings nearby, but also open fields and forest. The participants of most gardens were local residents who lived nearby, though three of the gardens received significant help from outside volunteer groups when it came to building and planting. Three of the gardens donated a portion of the produce they harvested to charities, while the remaining gardens allowed gardeners to take home their harvest.

Our gardens represented a variety of garden organizations, though faith-based organizations may be slightly overrepresented in our sample. Three case study gardens were associated with churches, one with the local extension office, one with a faith-based clinic, one with a faith-based educational organization. Four gardens utilized funding primarily from their associated organization, while two functioned separately, gaining funding from private donations. For a more detailed description of each of our case study gardens, please see Appendix B.

Based on our observations during focus groups, as well as interviews, our case study gardens appeared to have fairly equal numbers of male and female participants. Although all gardens welcomed gardeners from different races and ethnicities, the Refugee Garden was the only one intentionally tailored for a non-white population, and was therefore the only garden whose participants were not predominantly white. However, the County and Church Gardens both had non-white participants present in the focus groups. The average age of focus group participants appeared to be slightly higher than middle-aged (we did not ask them their ages explicitly), though individuals in their 20s and 30s were also represented. All gardens said that children and teenagers under age 18 also participated, though none of these individuals were represented in our data.

**Survey Respondent Demographics**

In the end, our survey received a total of 151 complete responses, and was opened 79 times without being completed. It was open to respondents from early January 2017 to mid-February 2017. The survey data included responses from a total of 107 gardens in 60 cities throughout
North Carolina.

Survey respondents had a mean age of 57 and a median age of 58.5, with the youngest being 23 and the oldest being 91. The majority of respondents were female, and a large majority of respondents were white (see Figure 3). 35% of our respondents were garden managers; another 35% were non-manager gardeners, and 30% described themselves as “other.” These “other” responses were generally individuals who acted in a volunteer capacity (e.g. activity leaders and educators), while some had a greater degree of input (e.g. co-managers and garden founders). The majority of respondents were highly educated (see Figure 4).

**Results**

This section is organized by research question and then by topic. These topic areas integrate complementary results from interviews, focus groups, observations, material culture, and the survey. They provide qualitative as well as quantitative information, and show how our different methods support and balance each other. Our case study data come from our six case study gardens, while our survey data include responses from a total of 107 gardens in 60 cities.

| RQ1: What types of land use and management choices exist that might lead to the presence of soil contaminants and pesticides in community gardens? |

**Land Use**

**Historic Land Use.**

Interviews and conversations with garden managers and participants gave us some insight into past land use of the gardens’ properties, though all participants made clear they do not know the full history of the lands they garden. Focus group participants shared that the Church Garden is on land that was potentially once a dump site, while the Refugee Garden is on land that has likely been a lawn for decades, according to the manager interview. The County Garden was the
site of a former sanitarium (County Garden focus group).

Managers at three of our six case study gardens suspect that the garden’s land was used for agriculture at some point in its history (Medical, County, and School, Garden interviews), which means there is a potential for legacy high level pesticide contamination. All of the six case study gardens were adjacent to or within 100 feet of buildings built before 1978, which puts them at risk for contamination from lead paint (from all garden observations; Wake County n.d.).

**Surrounding Land Use.**

During the gardens’ visits we observed that all our case study gardens were located within 500 feet from a road, and some were directly adjacent to a road, driveway, or parking lot. The County Garden was the closest to a major multi lane highway, but each of the six gardens was within approximately one mile of a road with heavy traffic. Two of the gardens were directly adjacent to a paved parking lot (County and Medical Garden observations). All of the six gardens were also within a few miles of commercial areas, some of which included dry cleaning operations (from all garden observations). Commonly observed external sources of contamination were motor vehicles, old buildings, and power structures, according to coding of the observation photos and observation checklists we collected at site visits (See Figure 15).

Many of the case study gardens were located next to properties managed by other parties. Participants at three of six gardens voiced concern about both residential neighbors and affiliated grounds managers, who use pesticides and herbicides, or potentially introduce other contaminants such as motor oil (Church Garden focus group; Medical Garden interview; Refugee Garden observation commentary). A survey respondent expressed concern about contamination from these sources as well: “I am concerned with the herbicides and pesticides our grounds division uses, but my use of these is very limited.”

Two case study gardens mentioned specific instances of potential contamination from surrounding sources. Some focus group participants at the Church Garden suspected the water used for irrigation in the garden could be a potential source of contamination. They were particularly worried about the presence of pharmaceuticals in the city water supply that could
likely contaminate their garden soil. In addition, when discussing commercial or industrial sites near the garden, an interviewee at the Refugee Garden mentioned an energy-generation facility nearby. He mentioned that he recalled that there was a coal ash spill that occurred 15 miles upriver of the garden in 2015.

**Management Choices**

At the six case study gardens we visited and studied, managers were involved with a suite of choices about all aspects of the garden’s physical and social structure (all garden interviews). From the start, managers we spoke to were involved in the initial design and construction of the garden layout and structure. They also worked on sourcing structural materials, soil, compost and fertilizer, chemicals and pesticides (both organic and synthetic) and plants and seeds. Garden managers were also responsible for maintenance and safety at the garden (including upkeep of structures, soil testing at times, etc.).

Beyond physical structural management of the garden, managers were also often in charge of managing the overall social structure of the garden: communicating with participants and outside partners, managing gardener involvement through plot applications or coordination of volunteer workdays, making and enforcing rules and property access, and managing finances. While we did gain insight into these social management choices during our study, with exception of communication systems, these were generally outside the scope of our research and are not reported here. Instead the following section focuses on physical management choices mentioned above.

**Garden Materials.**

One of the most notable results obtained through analysis of our observations, focus groups and interviews was the significance of materials’ sourcing to the management of community gardens. All of the case study gardens actively brought in large quantities of garden materials such as topsoil, mulch, leaves, manure, and compost, among others. The materials most often discussed by managers and gardeners and observed in the gardens and material culture were mulch (158 references), compost (71 references), manure (41 references), and leaves (30 references).
All six of our study gardens used mulch to some extent, mostly on pathways between plots. One garden covered the entire site with mulch (woodchips) to prepare it for gardening, expressing that they would wait a few years for it to begin decomposing and then mix it in. This site also layered the mulch with cardboard across the whole site (Church Garden observations). All six gardens also sourced manure to use in the garden. The mulch was most often sourced from municipalities or businesses that cut trees and tree limbs and provided mulch for free. Multiple of the case study garden managers mentioned that they took advantage of the free wood chips that came from municipal cutting of tree limbs around the city: “Local tree services will put you on a list, and when they're cutting down a tree in your area, chipping all the branches and everything, if you're on their list, they'll sometimes come in one day and there'll be a pile of wood chips, and that's what we cover our paths with” (City Garden manager interview).

All six gardens also brought in manure. Most often the manure came from individuals or farms that had livestock and were happy to give manure for free. The Refuge Garden manager shared some specific sources he used including an individual with a cow named Buttercup saying there was a photo where we “should be able to see (him) and Buttercup the cow, and the cow litter on (his) trailer”. He also sourced from a horse barn that was happy to provide it for free if he was willing to come and pick it up himself.

All six gardens used or created compost at their gardens. Compost primarily comes from composting of materials within the garden and from gardeners’ homes, but is also often bought from a business or sourced from the municipality or city. Managers we interviewed often mentioned getting compost and leaves that they then composted from the municipal collection system.

Survey respondents also cited the frequent use of compost materials in their gardens. Of the 50 garden managers surveyed, when asked “Do you use fertilizer in your garden? If so please describe.” 36 responded with some discussion of compost.

Use of Chemicals in the Garden.

During garden observations, managers generally described the types of chemical products they
used in their gardens. Additionally, we asked more in-depth questions about these products in the interviews. Four of our six case study gardens said they used RoundUp around the edges of the garden to control weeds (Church, County, City, and Refugee Gardens interviews). In fact, when discussing fertilizers and pesticides in our interviews and focus groups, the sixth most commonly used word was “RoundUp.”

Through interviews, observations, and focus groups, we identified that all of our six case study gardens used integrative pest management, meaning that they employed non-toxic methods of pest and weed control - such as manual removal and “natural” alternatives - before resorting to chemical pesticides and herbicides. Common “natural” alternatives managers mentioned include hand weeding or hand picking bugs, using things like mulch or newspaper to deter weeds, neem oil, diatomaceous earth, BT (bacillus thuringiensis, a naturally occurring bacteria that is bad for some bugs), companion planting to deter pests, and thrifty solutions like slug traps and noisemakers to scare away birds.

Our survey asked garden managers whether their gardens use various types of products. 56% of respondents said their garden used pest control products, 31% said their garden used weed control products, and 88% said their garden used fertilizers. Of these, there was a moderately even distribution of products that were considered “natural” or “organic” and inorganic or synthetic.

Other Management Choices.

Through the observations and interviews we found that at all gardens, managers make the choice to use raised beds. These raised beds were most often constructed with treated wood sourced from home improvement stores (post-2003, so less likely to contain arsenic but potentially containing other chemicals) and filled with soil also brought in from outside the garden (primarily sourced from businesses but with a wider array of sources than the wood). We found that none of the gardens we visited used railroad ties or treated wood from before 2003 as these both are a specific source of contamination concern (from all garden manager interviews). However, none of the gardens we visited capped the soil underneath the raised to create a barrier between the new soil they brought in and the existing soil (from all garden manager interviews).
If the purpose of the raised bed is to avoid exposure to contaminants in the soil that is already on the property, the lack of capping handicaps this attempt as roots, water, and other materials will cause mixing between the soils and move contaminants into the new soil in the beds. In fact, one of our managers specifically called out the issue when discussing that one of the reasons they used raised beds was because of the region’s problem with nematodes and ground pearls (another plant root pest present in soils) in the natural soils. Without capping, he explained, the nematodes and ground pearls would soon just moved up into the new soil beds and counteract their attempts to have safe soil for their plants (Refugee Garden manager interview).

Three of the six case study gardens used rain barrels or other rainwater collection systems. All of these systems collected water from old buildings (pre-1978) and used this water to irrigate edible plants at the garden. None of these gardens had tested the water from these barrels and none seemed to be worried about water contamination from this source. Depending on the constitution of these old buildings and their rooftops, water collection from these sources may be a source of lead contamination from paint or other contaminants from degrading synthetic materials. One focus group participant mentioned the rooftop where they collected water was made up of very old shingles that “are a petroleum product” and may be cause for concern (Church Garden focus group).

**Soil Testing.**

All managers at our six study gardens were aware of the free soil testing service provided by the North Carolina Cooperative Extension. Many of the managers had used this service, some more than once. Few managers however had taken time or had the resources to specifically do soil contaminant testing. The manager of the Refugee Garden had done soil testing for contaminants and was in the process of sharing that information with gardeners.

In the survey, 22% of garden managers said their garden has had its soil tested for contaminants, while 54% said their garden had not had its soil tested, and 24% of gardeners did not know if soil had been tested. Of the 11 gardeners whose soil had been tested, 44% said changes had been made in the garden based on the test results, while 56% said no changes had been made. Many managers had little difficulty in interpreting the results of their soil tests (see Figure 5).
**RQ2: What behaviors of community gardeners are present that might lead to exposure to soil contaminants and pesticides?**

Community gardeners themselves also have the power to affect contaminant and pesticide exposure during their time participating in the garden. Both the case study research and the survey asked questions about a variety of individual behaviors that may reduce or eliminate exposure to potential garden contaminants and pesticides. In this study we asked about wearing protective equipment (such as gloves), washing your hands, and washing produce before it is eaten (see Figure 6). Participants also mentioned some activities that may increase the likelihood of exposure to these contaminants and pesticides, for example children playing in compost or manure piles, or actively eating dirt while in the garden.

**Individual Behaviors**

**Washing Hands and Produce.**

Survey respondents tended to wash their hands and produce frequently, and wear protective equipment in the garden on a somewhat regular basis (see Table 2; Figure 7).

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<th>Never</th>
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<th>Often</th>
<th>Always</th>
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<tr>
<td>Wash hands</td>
<td>2%</td>
<td>20%</td>
<td>20%</td>
<td>57%</td>
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<tr>
<td>Wash produce</td>
<td>4%</td>
<td>9%</td>
<td>13%</td>
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<tr>
<td>Wear protective equipment</td>
<td>8%</td>
<td>37%</td>
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*Table 2. Frequency of survey respondent practices*
To understand the factors that influence these three behaviors, we ran three separate ordered logistic regressions. We used age, education, race and/or ethnicity, level of concern of health impacts, level of knowledge about health impacts and the presence of children in household as predictors. In addition, we clustered for the high response garden to ensure independence (See Appendix D).

The odds of increasing the frequency of washing hands is higher for people concerned about health impacts of contaminants: 3.97 higher frequency for respondents concerned about pesticides in their food, 0.32 higher odds for those concerned about pesticide application and 0.54 times higher for respondents concerned about soil contaminants. The odds of increasing the frequency of washing hands was also 0.88 higher with a higher level of education. For washing produce, we found that the odds of increasing the frequency is 0.68 times higher for those respondents more concerned about health impacts of pesticides in food, 0.36 higher for men. The frequency of washing produce odds increase 0.98 with a one unit increase in age. Overall, these regressions show that a higher concern about health impacts increased the frequency of washing hands and washing produce. Gender and age seemed to be statistically significant and positively correlated with washing produce only. It is relevant to point out, however, that even though the survey asked about frequency of washing hands after gardening, it did not clarify whether respondents performed this activity immediately after gardening.

Throughout the focus groups, many gardeners expressed that they did not feel a sense of urgency to wash their hands right after gardening. In reference to hand-washing habits, one focus group participant said, “if I can get a little water and splash it, a little shirt-wipe, okay I'm good to go. I'll use soap when I get home” (County Garden focus group). Using water without soap to clean hands was a common theme in our case study gardens. One manager recalled, “when they’re finishing up tending their plot and they’re taking their hose back and winding it up by the spigot, they normally wash their hands off and wash their feet” (Refugee Garden manager interview). Another gardener suggested that they would like something to wash their hands with, but didn’t want to have to remember to bring soap to every garden visit (County Garden focus group).
Focus groups and interviews gave insight specifically to participants’ produce washing behaviors. While the survey was clear that participants regularly washed produce, conversations with gardeners at our study gardens made clear participants regularly wash produce in their homes and kitchens, but very infrequently wash produce when in the garden. Participants from all three focus groups admitted to eating produce off the vine without washing it. On focus group participant shared that “you know, I don’t think we took in any cherry tomatoes this summer, because they pretty much ate them straight off the bushes” (Church Garden focus group).

**Using Protective Equipment.**

Another individual behavior of interest for our research was the use of protective equipment by gardeners. With the survey data, we performed an ordered logistic regression to see which factors can predict the frequency of using protective equipment. This regression shows that the odds of use increases significantly with concerns about health impacts of contaminants: 5.78 times for those more concerned about pesticides in food, 2.36 times for respondents with higher concern about application of pesticides and only 0.35 for those with a higher concern about soil contaminants. The odds of frequency of produce is higher with knowledge of health impacts of pesticides (2.418) and soil contaminants (0.627). Concern and knowledge of health impacts, particularly of pesticides was the main predictor of increasing the frequency of the use of protective equipment. We also see that in turn, having a higher education is a predictor of having a higher knowledge of health impacts of pesticides.

Moreover, during the focus groups we obtained more insights on the use of protective equipment by community gardeners. When it comes to wearing gloves in the garden, as well as other means to prevent exposure, gardeners from the focus groups mentioned that the inconvenience is not worth any potential health benefits that they were aware of. For instance, one focus group participant wished she could wear gloves, but lamented that it is not practical all the time (County Garden focus group). Another mentioned, “you go to pinch something, you go to pull something and it’s this much longer than your fingers” (County Garden focus group). See Figure 6 for the number of times these and similar behaviors were mentioned in our case study gardens.
Garden Participants and Activities.

Because of our particular interest in vulnerable populations such as children, we asked survey respondents (both gardeners and managers) about the participation of children under age 10 in the community garden. According to the survey, there is a high participation of children under age 10 in community gardens across North Carolina. Many survey respondents (32%) said that children under age 10 visit the garden *often*. It is also common for children to visit *sometimes* (29%). Finally, about one third of the gardeners replied that children visited *rarely* (29%). When in the garden, 74% of respondents say that children spend their time *helping adults garden*. *Participating in educational programs* (51%) and *playing in the dirt* (51%) are the next most commonly cited activities for children. Respondents generally indicated that gardeners spend *much of their time* in the garden working, and *a little of their time* relaxing, socializing, and playing with children.

Throughout the interviews in the case study gardens, garden managers mentioned that children visited the community garden commonly to participate in different garden activities including special events and/or regular work days (Refugee, City, Medical, School Garden interviews). One of the interviewees mentioned that the type of activities they perform in the garden depends on the age—teenagers seem to help more with gardening activities, whereas younger children “play on their own around the garden” (Refugee Garden manager interview). Both the survey responses and the interview information seem to indicate that some of the activities performed by children may not have adult supervision, for instance playing in the dirt. A notable discrepancy in the survey data is that managers estimated gardeners spent more time playing with children than gardeners reported. Additional activities listed for participants in the garden included: eating, planning, learning about gardening, teaching children, and sharing advice.

Garden Produce Consumption.

Choices about who consumed the produce was also of interest as this related to who may be exposed to contaminants through consumption. Three of our case study gardens included food donation as an explicit part of their gardening management, meaning that the consumers of garden produce included individuals who may never have visited the garden, and were
potentially at greater risk for food insecurity or health problems. Three of our gardens also
focused on providing space for personal gardening, meaning that the gardeners themselves, as
well as their families and friends, were the ones consuming produce.

In our survey, we asked garden managers to select all groups of people that consumed produce
from the garden (see Figure 8). The majority of managers (62%) said that the gardeners
themselves consumed produce, but gardener friends and family, food banks, and local residents
were also common responses. It was very common for a garden to provide produce to more than
one group of people.

**RQ3: What are the primary barriers to and motivations for changing those behaviors?**

To answer our third research question, we first looked into what level of awareness and
knowledge participants possessed on the topics of soil contamination and pesticide use in
gardens as well as their level of concern on these topics. As discussed in the health belief model,
behavior change is dependent not just on motivations but also on an awareness of the individual's
vulnerability to the threat at hand and their concern about that threat (Rosenstock et al. 1988).
So, understanding awareness, knowledge and concern are vital to understanding barriers and
motivations to behavior change. After discussing awareness, knowledge, and concern, this
section will share specific motivations and barriers identified through analysis of interview,
focus group, and survey responses.

**Awareness and Knowledge**

**Soil Contaminants.**

Based on results from the focus groups and interviews, gardeners generally exhibited a wide
range of awareness levels when it came to contaminants. Some individuals were able to suggest
arsenic, lead, and others by name, and correctly identify their sources, while other individuals
struggled to articulate the ways in which contaminants might affect health. Garden managers
tended to have a higher overall understanding and familiarity with contaminants, and had
generally given significant thought to potential sources of contamination, even if their
understanding was not exhaustive. When provided with basic information on potential contaminants and exposure and then asked to share their ideas and experiences, nearly all respondents were able to think critically about potential sources of contamination, both in their specific garden and in general. See Figure 9 for a breakdown of the frequency of mentions of various types of contaminant.

Gardeners participating in the three focus groups tended to be more aware of lead than other soil contaminants (County, Church, and Refugee Gardens). The word “lead” was specifically referenced in focus groups 20 times. When asked what contaminants may be present in the garden one focus group participant said, “lead from paints, obviously” as the first to come to mind (Church Garden focus group). Another participant mentioned torn down buildings as a potential source of lead contamination: “In neighborhoods where the house has been taken down, we've got to do lead testing of the soil” (County Garden focus group). In fact, “lead” was the 15th most commonly used word in situations where focus group participants were talking about contaminants. These data were collected through a word frequency query done on any transcription of focus groups that was coded to any of the “contaminant” nodes including chemicals, pathogens, heavy metals, and specifically named contaminants.

Gardeners and managers at our six study gardens as well as survey respondents were also able to specifically name a few other contaminants. At least one participant at each of our three focus group gardens (County, Refugee, Church Gardens) were able discuss arsenic in treated wood in a well-informed manner as well as discuss their active choices to avoid that contaminant source. A focus group participant, for example, was able to finish the presenter’s sentence when she hesitated after saying “wood was treated with, you know…” The participant instantly jumped into replying “arsenic, yeah it was treated with arsenic” (Church Garden focus group). Copper and zinc were specifically discussed most often in relation to manure and to the Cooperative Extension’s soil nutrient testing service. Two of our managers mentioned these contaminants in their interviews, one discussing how they “realized [the turkey manure] had high zinc content” (School Garden manager interview) so they did not use it for the garden, another discussing how the extension office’s soil nutrient tests include zinc and copper, which helped them discover their manure was safe of these contaminants (Refugee Garden manager interview). A survey
respondent also mentioned “routine soil tests did show a high level of zinc” in their garden which they addressed by “deep plowing and extra lime”.

In interviews with the garden managers, we found that they had several different perceptions of the gardeners’ level of knowledge on potential contaminants in the garden. One garden manager believed that her gardeners were for the most part well-informed about contaminants and the health issues that could result (Church Garden manager interview), while another manager believed her gardeners were largely uninformed (County Garden manager interview). The manager of the Refugee Garden believed that the gardeners had not considered potential contamination since it was not a major issue in their country of origin (from manager interview).

**Externally Sourced Materials.**

Managers and focus group participants alike often expressed a level of awareness of potential risks associated with materials that were brought into the garden from external sources. When prompted to discuss what may be a concern in their specific garden, gardeners and managers often discussed manure, mulch, and compost being potential sources of external contaminants. Awareness was commonly associated with concern about not controlling the lifecycle of the material and the potential for contamination before it got to the place it was sourced from. When sharing concern about the municipal compost they bring to the garden, the County Garden manager expressed in an interview: “They don’t know where it comes from, you know, it can come from a landscaper, it can come from the leaves collection. You know, it could come from a homeowner who has bagged-up their grass clippings so there's no way to know.”

This same garden manager shared her own personal experience with one of the sources of this municipal compost, explaining that “what people do is that they blow all their leaves into the street and they leave them there for these vacuum trucks to come around and pick up... sometimes they sit there for a month or two at a time before they're vacuumed up. And people driving over them, and so, what, you know is there a potential for there to be a hazard material that might be in there”. The City Garden manager also shared some insight into the source of one of the materials they used extensively on their property: “wood chips [...] from companies who come in and trim for power cut lines and people who wanted leaves taken off of whatever.”
These and other conversations demonstrate that managers are aware that material sourcing is a large part of their operation and some of these materials may be a potential for concern. Yet, managers often seemed to be equally unaware of potential for contamination associated with other materials. Cardboard, for example, was a commonly used material, but managers and participants rarely if ever showed concern about potential contamination from this source (Church and County focus groups). Ultimately, participants were open about their inability to track down and understand whether they should be concerned about sourced materials and about what specifically.

**Land Use Information.**

It was common for gardeners in the focus groups to be unaware of the site’s land use history, and to be uncertain of how this history can impact current contamination. Based on the interview data, garden managers had a better sense of the land’s history than garden participants, but did not always have sufficient records to account for more specific uses or uses in the distant past. One manager told us, “I just don't have any records of what the land was used for” (County Garden manager interview).

All focus group participants had a basic awareness of where the garden was situated relative to sources of runoff, roads, and other obvious sources of contamination. A focus group participant at the County Garden mentioned “just basic water runoff that comes with things it gathers as you go” as a potential contaminant source, while another participant expressed concern to their manager about the parking lot adjacent to the garden plots. Participants in the Church Garden focus group expressed awareness of “runoff from businesses that are spraying”, “stormwater runoff”, and “runoff coming in from the parking lot” to name a few. In reference to chemical weed control products, a participant in this same focus group mentioned, “I'm curious about what our neighbors are doing.” However, when it came to the location of dry cleaners, gas stations, and other commercial sites that may be external sources of contamination, gardeners and managers alike were often unsure.

The land-use-associated source of contamination that participants at our six study gardens were most aware of by far was old buildings as a potential source of lead paint.
Pesticides.

Gardeners care not only about knowing where their food comes from, but also about having a choice in how to grow it. Most of the garden members interviewed recognized that there are certain products used for gardening that can be detrimental for your health and the environment (Church Garden manager interview). There was a general awareness among community garden members in our study about the benefits of growing produce in an environmentally-friendly manner that respects the natural ecological processes (NCCGP, 2017; Church Garden interviews).

Based on a combined analysis of the survey, focus group and interview data, both garden managers and gardeners seemed to be highly aware that pesticides could have potential health impacts and how to stay safe from these impacts. Indeed, one survey respondent voiced frustration at the general trend towards fearing pesticides: “When used correctly, pesticides are safe and effective. Too much misinformation that people believe is true.” Another focus group participant shared understanding of safety precautions in expressing that “one of the things that (manager) always talks about is that if you are going to use insecticides or herbicides or whatever, you know read the label directions and stuff” (County Garden focus group). In addition, some gardeners had more extensive awareness of pathways for these chemicals to cause harm, but the actual health impacts of pesticides were rarely mentioned.

Based on our analysis of the focus group and interview data, gardeners tended to be aware of garden policy regarding pesticide use, as well as where and how often chemicals were applied. Garden managers exhibited an overall awareness of whether gardeners were using pesticides, though they also admitted the possibility that they had missed some gardener behaviors. In addition, several garden manager survey respondents said they struggled with managing gardener behavior; one manager lamented that “it takes many repetitions of facts and instructions to produce the desired behavior” among gardeners.

Survey Respondents’ Self Assessed Knowledge and Concern.

In the survey, respondents were asked to rate their degree of knowledge about soil contaminants
and pesticides. This was not explicitly testing knowledge, but rather self-appraisal of knowledge, and was related to awareness of contamination topics. 47% of respondents said they knew a moderate amount about the potential health impacts of pesticides, and 37% said they knew a moderate amount about the health impacts of soil contaminants.

In order to know what variables were causally related to self-assessed knowledge of health impacts of soil contaminants (abbreviated ksoil) and pesticides (abbreviated kpest), we ran two ordered logistic regressions\(^1\)\(^2\). We used age, education, gender, race and/or ethnicity and concerns about contamination as our explanatory variables, and we clustered for the County Garden because of the high response rate from participants of that garden (around 10% of respondents). We found that being part of the County Garden, age, education and race were positively correlated and statistically significant predictors for ksoil. As for kpest, only education and concerns about health issues related with pesticides in food were positively related and significant explanatory variables.

For health impacts of soil contamination, the odds of being in a higher category of knowledge is 1.06 higher when age increases by one unit. The odds of knowing more about soil health increases by 0.62 with a higher level of education, and is 1.84 higher for the non-white gardeners. For health impacts of pesticides, the odds of being in a higher category of knowledge is 0.64 higher with a higher level of education. The odds of knowing more about health impacts of pesticides are 4.29 higher when respondents have a higher concern of pesticides in food.

There are two main takeaways from this regression. First, it seems that a higher education level seems to increase both knowledge of health impacts of soil contaminants and pesticides. Second, age and race (being non-white) were positively correlated with knowledge of health impacts of soil contamination but they weren’t statistically significant for knowledge of health impacts of pesticides.

In a related question, the survey asked gardeners how concerned they were about the health impacts of contaminants: 76% of respondents said they were very concerned about the health

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\(^1\) Both models comply with Independence and proportionality of odds assumptions.
\(^2\) See Appendix D
impacts of consuming produce with pesticides on it, and 51% said they were very concerned about the health impacts of soil contaminants. To understand which independent variables could predict both concern about health impacts of soil contaminants (abbreviated consoil) and concern about health impacts of pesticides application (abbreviated conappest), we ran two ordered logistic regressions\(^3\) \(^4\).

In terms of health impacts of soil contaminants, the odds of being more concerned is 1.29 higher for gardeners that know more about soil contamination. Education is also positively correlated with concern. Having a bachelor’s degree increases the odds of being more concerned by 3.35, and having a master’s or PHD increases the odds by 1.31. In addition, the odds of being more concerned also increases by 1.44 if one of the gardeners’ motivations is feeding the family and by 0.82 if they are non-white. As for health impacts related with the application of pesticides, the odds of being more concerned is 1.99 higher for gardeners that know more about pesticides. The odds of being more concerned about the application of pesticides increases by 10.45 when gardeners are also concerned about health impacts of pesticides in their food. Summarizing, the main takeaways of the regressions of concerns about health impacts are: i) a higher knowledge of health impacts will increase the odds of being more concerned about health impacts of both soil contaminants and pesticides; and ii) a higher level of education is statistically significant and positively correlated with a higher concern of health impacts of soil contaminants but not for health impacts of pesticides.

\textbf{Motivations}

\textit{Motivations for Community Gardens.}

In our case studies, interviewees were asked directly “What are the main goals of this community garden?” Focus group participants were not explicitly asked about their motivations for participating in a community garden, but mention of motivations often arose through discussion of gardening choices. These types of motivations are relevant to our study, because they help us understand what types of messaging are likely to be impactful, based on gardener priorities. The

\(^3\) Models comply with independence and proportionality of odds assumptions.
\(^4\) See Appendix 1
most common motivations mentioned were community engagement, food security, and improved health (see Figure 10). Individuals also mentioned cheap produce as a motivation, although it was always a secondary motivation or afterthought rather than a primary driver: “More than anything people come enjoying the fact that it is, it gets them outside, it gets them active and it does to an extent cut down on what they would pay for fresh produce” (County Garden manager interview).

In the survey, we asked participants to select from a list of potential motivations for gardening, allowing gardeners to select all that they felt applied to them. These included growing food to feed a family, spending more time outside, getting more physical activity, socializing with other community members, getting in touch with nature, and “other.” We created these categories based on existing literature about community gardens, as well as recurring content we found on community garden websites. The results were fairly evenly distributed across all categories, with nearly half of all respondents citing any given motivation (see Figure 11). Most respondents selected multiple motivations. On average, respondents cited just over three different motivations as applying to them.

**Motivations for Gardening Choices.**

In order to encourage positive behavior change, it is important to understand what factors are likely to motivate gardeners to adopt new practices. Therefore, in addition to researching what motivated participation in community gardening as a whole, we looked into what motivations affected an individual’s gardening choices while at the garden. Participants in the six study gardens were often motivated by their preference for natural or organic practices and lifestyles (see Figure 10). When discussing motivations in interviews and focus groups, participants used the word “organic” 74 times, and it was the 10th most commonly used word in this context. These data were gathered from a word frequency query inside of the “motivations” node which compiled coding for all times a gardener mentioned or alluded to a motivation for gardening or starting a garden. This motivation regularly was discussed in association with choices about pest control methods. In all the instances the word organic was used (89 uses in total through all of the transcripts), the word “pesticides” was the 4th most commonly used word within 5 words of
“organic”, after “garden”, “use”, and “know” (with stemmed words). So, the word “pesticides” is the most commonly associated word with the word “organic” that references a specific concept.

In open-ended questions, survey respondents used the word “organic” 38 times, many of those instances were suggestions that a natural or organic gardening style reduced the degree to which they needed to worry about contamination, which indicates that safety is a major factor underlying this motivation. Furthermore, only about half (56%) of survey respondents that were garden managers said their gardens used pest control products, some of which would be considered organic or natural.

Similar to this, participants often specifically cited their passion for healthy soil while gardening. This was a motivation for choices like what inputs to use or whether or not to use chemicals. When one focus group participant asked what they can do to make plants grow bigger and stronger another replied “Organics. Get the microorganisms going. Cause they’re the ones that will actually make the soil healthy. Fight off disease and bugs and everything” (Church Garden focus group). Another focus group participant stated that “healthy soil means healthy plants, healthy plants are more defensive” (County Garden focus group). Multiple participants from each of the six gardens cared about soil health for one reason or another, always “trying to improve the soil, at least a little bit every year” (Church Garden focus group).

Some choices were also based on a desire to reduce pathogens in garden materials and beds. Interestingly, when asked to brainstorm what contaminants may be present and ideas for reducing contaminant exposure, participants often got off into talking about pathogens and pathogen reduction. This shows pathogens are something that participants are both quite aware of and knowledgeable about as well as motivated by in gardening choices.

**Overarching Motivations.**

In the focus groups, interviews, and survey, two main motivations stood out that are discussed in more detail below. Community engagement, and food security.
Community Engagement.

The reasons for gardening most frequently cited in our focus groups and interviews match the set of “deeply shared values” mentioned by the NCCGP: community engagement, empowerment, inclusivity, food access and sustainability. This was also supported by the survey, in which 55 respondents said that socializing with their community was part of the reason they participated in the community garden.

In general, gardeners in our case studies recognized the value of their garden in creating a sense of community. From building fellowships and friendships among individuals with similar goals, to bringing people “from all sorts of different walks of life together” and creating “a community of communities” (County Garden manager interview). By coming together as a team, community members have the capacity to turn their garden into a valuable asset in their neighborhood (NCCGP 2017; Church Garden manager interview).

One manager explained that a community garden grants, “access to a place to grow, and a community of people who enjoy growing” (Church Garden interview). Another said that gardeners achieve, “fellowship, friendship. I think it's a really big part of it. It's a great group of people and we love to laugh together and talk together and visit and just hang out” (Church Garden manager interview).

This sense of fellowship was so strong that another manager said, “in fact, there's people who participate in the garden who hardly ever bring anything home. They just do it because they enjoy gardening” (City Garden manager interview). The same person gave testimony to the efficacy of community gardens in achieving this: “I feel more connected to the community now than I was before we started the garden.”

Indeed, many gardeners brought up not just community engagement, but specifically engagement of disenfranchised communities. A manager said, “we specifically wanted to reach out to people who were low income and/or say, senior citizens, or disadvantaged communities” (Church Garden manager interview). Another garden makes sure “the membership fee amount remains low in order to encourage participation of low-income households in sustainable living
and gardening” (Church Garden interview), Even another manager referred to this motivation specifically by expressing his concern that “we have very few minority master gardeners, particularly black master gardeners” and sharing that “I’m trying to do something about that” (Refugee Garden manager interview).

Education was also a large component of the motives for and means to engage communities in community gardens. Three of our six gardens regularly engaged volunteer groups including school classes, Boy Scouts, and Girl Scouts, generally making efforts to teach skills while working in the garden. Garden members and managers regularly expressed that they have “learned a lot by participating in this garden” and many see this as a benefit of being involved. In general, participants and managers especially considered their community garden to be a learning platform, identified as “a place where we teach and we learn some” (Church Garden interview).

**Food Security.**

Improved food security was frequently a component of the missions of our six case study community gardens. Several of our case study gardens donated produce to charities or directly distributed it to people in need, while others specifically brought in food-insecure people to become gardeners. One manager explained that part of their mission was “to give people who otherwise don't have access to a place to grow a chance to grow their own food, and learn how to grow their own food. That's primarily what we're all about” (Church Garden interview).

Another manager suggested that improved nutrition was a significant benefit provided to the community garden participants: “Number one was to get them out and get them mixing together, and provide some fresh food for them. We have a number of food desert areas, and that is one of them” (Refugee Garden manager interview). Some gardens take special care to ensure their garden reaches those in need: “We have a goal of approximately 10% of the food grown to be donated to local [City] food pantries” (Church Garden manager interview).

According to the survey, 56% of individuals that responded to a multiple-choice question about why they were motivated to participate in community gardens answered, “helping to feed myself
or my family”. While not all of these families were necessarily food insecure, this fact does suggest that participating in a community garden does contribute significant food to a household.

**Barriers to Behavior Change**

**Cost, Time, and Resources.**

“Price may have been the guiding force for installing the community garden”.

Survey respondent.

Limiting financial expenditures appears to be a primary motivating factor for many decisions made about the management and use of community gardens. Our results suggest it was common for managers to make choices to save the garden money, citing common idioms like “beggars can’t be choosers” (Church Garden interview) or “we’re not looking a gift horse in the mouth” (Church Garden interview). All six case study gardens chose their location based on the availability of free land. Economic resources and land availability are common limitations reflected in the selection of land to create a community garden: “When you are given a vacant lot because the houses have been torn down—they [garden founders] jump at the chance of getting land and they don’t think about what might be under there.” (County Garden manager interview). Cost, convenience and proximity to the community explain why gardens could be established in plots with or around areas where previous land uses could potentially increase exposure of contamination.

In addition to the establishment of the garden, economic resources can be a barrier for garden management choices. One North Carolina community garden manager said that the biggest challenge in maintaining a safe garden was the “expense of routinely repeating soil tests for heavy metals.” (Survey respondent).

In addition to limited economic resources, other limited resources such as insufficient community involvement and time limitations for those involved acted as significant barriers to many aspects of garden success and health. For instance, one garden manager expressed that they use of chemical fertilizers because they have limited time and wanted to quicken the process of
soil conditioning (Church Garden manager interview). Many garden managers expressed that they used pesticides to limit the growth of weeds because they did not have the time or participant involvement to keep up with manually weeding (School Garden manager interview).

“Increasing the knowledge and cooperation of gardening participants” is key to maintaining a safe and healthy garden (Survey respondent). However, a commonly found barrier to increasing cooperation of gardening participants through the creation of an inclusive environment and a sense of belonging to the community, was language differences between gardeners. A recurrent topic in the garden interviews and focus groups was the difficulty of communication with non-English speakers (Refugee and School Garden manager interviews):

“I know most of the gardeners pretty well, you know, by being in the garden taking an opportunity to get to know them, but when you have a language barrier like that, you know, it’s hard to communicate.” (County Garden manager interview)

**Access to Information.**

Limited resources availability and language barriers were found to hinder communication efforts in the community gardens. As a garden manager (County Garden manager interview) mentioned, with limited manpower/hours, it is difficult to translate communication materials or interpret informational sessions regarding any relevant topic for garden members.

In addition to the limited access to information caused by language and resource limitation, a common concern was the lack of research done on chemical pesticides or mistrust on the existing sources of information. Some of the interviewees mentioned a fear of potential biases of the sources for pesticides: “I would feel better about the research if it hadn't been done by people that were affiliated with Monsanto. I don't trust the research that has been done thus far because it’s too tight to the industry that is making it.” (Church Garden manager interview).

**Apathy and Lack of Concern.**

We found that lack of concern can be a barrier that affects the management of common spaces, such as a community garden:
“Community gardens are naturally decentralized, and so suffer tragedy of the commons. People don't wash their hands because it's "good for the garden". People throw whatever-the-hell in the compost (oyster shells). People use any wood around to build a raised bed, not really caring if it might have lead-based paint. Since community gardens are typically organizations of volunteers, it's a delicate matter to reprimand; and since community gardens' strength is in diversity, it's tough to "build a culture" of anything, including safety.” (Survey respondent)

As this survey respondent mentioned, the strength of community gardens lays in its diversity. But this diversity can also make the task of increasing awareness of soil contaminants and chemical pesticides, difficult. One of the key actors in the largest garden for our case study argued that lack of concern on the application of chemical pesticides in the garden seem to be related with age. Older generations that “used seven in their gardens all their lives” do not consider the use of chemical pesticides as a potential health problem (County Garden manager interview).

**Compounded Barriers: Soil Testing.**

Getting soil samples tested brings its own suite of barriers. Perhaps the most fundamental was misunderstanding what a contaminant soil test was: a significant number of respondents, both in our case studies and in the survey, did not know that there was a difference between nutrient testing and contaminant testing. They tended to think that if their free county soil tests came back without warnings, that their soil was safe.

The next barrier to contaminant testing was cost; each sample costs $28 per contaminant, which is prohibitive - or at least dissuasive - to some garden managers. They would have to justify this cost to the gardeners, as well as know which contaminants they needed to test for. Furthermore, many gardeners did not know how to go about this testing, or what organization they needed to contact. See Figure 12 for the distribution of reasons cited for not testing soil for contaminants.

Even when community gardens are able to implement soil samples, a recurring comment from key participants and survey respondents was the difficulty in interpreting the analysis results: “I spent a lot of time researching what levels of heavy metals were dangerous. I found conflicting
numbers from different reputable sources.” - Survey respondent.

Furthermore, once gardeners receive results from contaminant tests, they need to know what actions to perform to address the potential for exposure. It can be difficult to find this information, some of the solutions may not be feasible, or the garden may not have enough resources to implement recommended solutions. See Figure 5 for a breakdown of how difficult garden managers find various parts of this soil testing process.

**RQ4: What are the most commonly used and trusted modes of accessing and dispersing information on soil contaminant and pesticide topics?**

**Information, Communication, and Education**

Internal communications within the gardens were primarily conducted through social media, according to our case study gardens. Signage was another common mode of communications, and emails were also integral to many garden managers’ communications with garden participants. See Figure 13 for a breakdown of all internal communications methods.

Gardeners most often get their information from websites and other gardeners. Many also use cooperative extension offices or other garden-associated institutions (such as an arboretum or nursery) to get information. There is a strong preference toward academic, university associated resources, particularly NC State’s website and resources. Gardeners also often cite learning from workshops they have attended or their garden associated organization put on. Figure 13 also shows which sources of information were most prevalent in our case study analysis; by far the most commonly observed in our case study gardens was the use of signage, which was created by garden managers.

Many gardeners rely heavily on their own personal knowledge and personal history with gardening to guide their choices. A large portion of gardeners interviewed were Master Gardeners, and regularly mentioned knowledge and resources gained from that expertise. The majority of gardeners discuss their childhood experience gardening and what they learned from
their parents and grandparents as a large part of how they learned to garden and what they base their gardening choices on.

According to the survey, the internet, along with organizations that support community gardens, are the two most commonly used information sources (see Figure 14). We ran a series of logistic regressions to see how education, age, gender, race/ethnicity and children in household affected the selection of information sources. We found that a unit increase in age increased the odds of selecting gardeners, manager, internet, organizations and library as potential sources of information in some capacity. The later we believe, is more a reflection of the way the question was set in the online survey than an actual explanation of which sources do the survey respondents find more valuable. Being non-white and having children in the household increases the odds of selecting the internet as a source of information. Being male and having children in the household increases the odds of selecting organization as a source of information. Being non-white, male and having children in the household increases the odds of selecting gardeners as a source of information. Being male and having children in household increases the odds of selecting organizations as a source of information. Finally, a higher education and being nonwhite increases the odds of selecting library as a source of information.

On the survey, we asked respondents to rate which types of information source they trust most. Respondents tend to trust information that comes from universities very much (74%), information from organizations that support community gardens very much (84%), and information from government agencies somewhere between some (42%) and very much (46%). They also tended to find the following sources very helpful: internet (74%), books (68%), and events and workshops (80%).

**Results Summary**

To understand what contaminant and exposure issues may exist in North Carolina community gardens our results have shared information on land use, management choices and individual behaviors. All case study gardens were near or next to buildings built before 1978 and were thus at risk of lead paint contamination. We discovered that surrounding roadways and parking lots as well as neighbor use of chemicals were a common potential surrounding land use source of
contaminants. This was matched with a common concern from gardeners about contaminants coming from runoff. The most significant management choices discovered in our research were materials sourcing and chemical use in the garden. Soil testing and the great deal of confusion associated with how to do it and what to do with the results was also a significant part of managers’ impact on the garden. Individuals’ choices on hand washing, produce washing and use of protective equipment was varied and interwoven with different barriers and motivations. Primarily, participants often did not use gloves or other protective equipment, and though they often washed produce in their homes, they rarely washed produce when eating it of the plant while in the garden. These behavioral choices were tied in with inconvenience and apathy.

To understand what primary barriers and motivations existed to promoting healthy management choices and individual behaviors we examined awareness, knowledge and concern on the this topic in the gardeners we worked with. Participants were much more aware of pesticides and their health effects than they were of soil contaminants, though participants were quite aware of lead specifically. Understanding of the lifecycle and contamination potential of externally sourced materials was a common issue expressed by managers and observed in our research. Lastly, access to land use history records was an informational challenge. We also pointed out specific motivations, especially finding the significance of community engagement and food security to all aspects of gardening, and barriers such as lack of economic and other resources, access to information, and apathy. Here again we found soil testing was a large issue that combined many interconnected barriers and awareness issues and challenges.

Finally, to discover the best way to educate and communicate these topics to gardeners, we studied the communication pathways and trusted information sources already in use by our study population. Managers most often communicated with gardeners through signage in the garden and email communication. Gardeners, on the other hand, preferred word of mouth when communicating among themselves. Gardeners and managers alike most often went to the internet for information on gardening in general and contaminants specifically. Participants also had preferences for academic sources of information and organizations that supported community gardens, especially the cooperative extension offices and NC State.
Discussion

To inform the future work in the community gardens project, the Duke Superfund Research Center has asked us to provide the baseline understanding of the following topics to inform their work and their choices of what to focus energy and resources on moving forward.

1. What are the main things we need to raise awareness and educate about?
2. What do we need to focus on to change behaviors?
3. How do we best communicate our findings, resources, and behavior change messages?

To answer these questions, we first look to what our research found to be the largest potential sources of contaminant exposure in North Carolina community gardens. This will help inform what is most important to focus on for education as well as what we need to focus on for behavior change work. We also take into consideration what the current level of understanding, awareness, and knowledge on these topics are in order to identify what to base our education on and what gaps need filling. To work toward behavior change, we must understand gardeners’ motivations and barriers to taking action on these topics. Finally, to best communicate our findings, we look to our research on how gardeners communicate and learn about these topics and what messaging is most effective.

Significant Potential Contaminant Exposure Concerns at North Carolina Gardens:

According to our research, the three largest potential causes of contaminant exposure at gardens around North Carolina are: land use practices surrounding the garden, the lifecycle of materials brought into the garden, and the lack of gardeners’ appreciation of individual protective behaviors.

**Surrounding Land Use.**

Surrounding land use and practices is a significant potential source of contaminants. Use of synthetic pesticides, fertilizers, and other chemicals like termite treatment in neighboring properties or by managers of the land surrounding the community garden is a common source of concern by managers and gardeners. Often bad relationships or lack of bargaining power in relationships with these players made it difficult to communicate and compromise about land use
choices that were affecting the garden. For example, gardens in neighborhood areas were stressed by neighbors’ use of chemical pesticides, gardens adjacent to buildings owned by the institution that provided the land for the garden were concerned about termite treatments on the buildings, and gardens surrounded by land managed by grounds crews were upset by regular application of chemicals right up to the edge of the garden. Another large external source of potential contaminants that was apparent at every garden visited was motor vehicles and roadways. All gardens were within a mile of a major roadway (often multi lane highways). Many research participants voiced concern over runoff from roads and parking lots adjacent to gardens.

Garden Materials Sourcing.

While initially we expected previous land use on the garden property, and adjacency to major pollutant sources to be a large source of contaminant concern, we did not consider the significance of garden materials brought in from outside. Many of the gardens studied were very involved with utilizing progressive, savvy gardening techniques such as raised beds for their growing, mulching pathways or laying down cardboard for weed suppression, and composting their scraps from the garden and homes. These practices meant a great deal of materials were being brought in from outside the garden, sometimes almost every single part of the garden from the soil to the structures were brought in from outside, leaving little to no connection to the actual land they were working on.

While managers and gardeners were not initially conscious of the potential risks associated with external materials sourcing, they were quick to realize and offer up this as a potential hazard as we began to talk with them. Lack of risk awareness came up more often with materials that were used in unique situations such as cardboard. Although there are not many resources related to cardboard as a potential source of contamination, there has been some discussion and research on the potential exposure to BPAs and other chemical residues from paper and cardboard used in food packaging (Lopez-Espinosa, et al., 2007). Yet, overall, whether or not managers and gardeners were aware of the risks associated with these materials, reducing contamination was largely out of their control. This means control, not awareness, may be a larger barrier here.
As a result, the significance of this potential source of contaminant exposure is based on 1) the fact that vast quantities of these materials are being brought in on a regular basis, 2) the fact that their life history before arriving at the garden is unknown or uncertain, and 3) the fact that there are a variety of possible opportunities for these materials to become contaminated before they make it to the garden.

It was interesting to see in our analysis that far and beyond the largest factor in choosing and sourcing materials for the gardens was what was the cheapest or what was free. This is consistent with our analysis of barriers, that found cost was a key factor in garden management choices. Particularly we found that many gardens sourced materials from municipally affiliated sources that provided mulch, compost, leaf litter or other materials for free or cheap. Materials sourced from municipalities such as compost, leaf litter, or mulch is often collected from a wide array of sources, or even crowd sourced from the community (when you drop off your yard waste at the landfill for example) and is also often entirely unregulated. This is a problem for gardeners as they are unable to trace where the materials originally came from or what may have gotten into the materials they are now using in their garden along the way. This issue also ties back into the roadway contamination issue in situations such as leaves blown into roadways and picked up for municipal composting.

Previous research, such as Cozier et al., 2016, explores the potential contaminant risk associated with treated wood, compost, burning trash, and pesticides. This research supports our findings that these garden materials are an important potential source of concern. However, there is a lack of research on the topic of mulch and leaf litter brought in to gardens and potential contaminants it may bring with. This may be because there is no concern associated with these materials, or it may be due to a gap in the current research on these topics. Our findings that mulch is a widely used, externally sourced material is supported by resources such as the EPA’s guidance on Brownfields and Urban Agriculture (US EPA, 2011b) which encourages use of mulch on pathways in gardens. This resource goes one step further and even recommends gardeners work with their local municipality to source free compost or mulch. It is clear that these materials and sources are widely used in gardens and warrant further research and
consideration due to their potential to have a large effect on gardeners’ health if they do in fact bring contaminants into the garden.

The third significant potential cause of contaminant exposure is gardeners not utilizing individual protective behaviors. Overall our analysis found gardeners don’t wash hands, wash produce, use gloves, or use protective equipment (when handling chemicals) consistently if at all. Individuals generally did not see any value in use of these protective behaviors and found them inconvenient or unnecessary. In this situation, the health belief model is directly applicable. While gardeners do seem to be aware that using gloves and other protective behaviors will protect them from contaminants in the soil or pesticide exposure, the issue seems to arise in that gardeners do not believe they are vulnerable to these threats. Regularly individuals we spoke with would express that they would use these precautions or should use these precautions, but don’t because they don’t feel they are necessary or important. The main barrier to utilization of individual protective behaviors seemed to be the lack of awareness of what potential contaminants and pathways to exposure might exist that these behaviors are protecting gardeners from.

**Current Levels of Understanding, Awareness, and Knowledge.**

Analyzing awareness of the health issues associated with synthetic pesticides is a good baseline from which to examine understanding and awareness of soil contaminants among community gardeners. In recent years, there has been a rise in cultural awareness of pesticides and their relationship with food and health (GRACE Communications Foundation, 2017). This general cultural awareness was reflected in our research with managers and gardeners alike showing a high level of both awareness and understanding of pesticides in their gardening activities and on their food. Being organic and natural was a large motivator for many gardening choices, and as the survey analysis and regressions showed, knowledge and concern about pesticides was a predictor of many other behaviors and choices.

This awareness of pesticides did not extend to soil contaminants. In the survey analysis, we found that a higher concern about health impacts of pesticides seem to increase the frequency of individual behaviors (i.e. washing hands and produce) significantly more than the concerns about health impacts of soil contaminants.
Just as in the case of awareness levels, knowledge of health impacts of soil contamination seems to be more limited in the community gardens. The majority of research participants at the case study gardens rarely actively thought about soil contaminants in any aspect of their work and choices at the garden. When participants did bring up contaminants they were aware of, they were specific cases such as arsenic in treated wood, lead from old paint, or zinc from turkey manure. This pattern of knowledge seems to show that gardeners’ awareness of these contaminants are associated with an awareness of a particular material or specific situation that may produce the contaminant. This “source oriented awareness” as opposed to “contaminant oriented awareness” helps shed light on how gardeners may most often be learning about these contaminants and suggests that gardeners most readily conceptualize these issues when it is associated with a concrete source. This is consistent with the health belief model established by Rosenstock et al. (1988), that explains individuals are less likely to respond to amorphous threats, but instead they need to understand how this threat makes them vulnerable and believe that the behavior with have a direct and immediate impact on the threat.

Many participants openly admitted soil contamination in gardens was something they hadn’t considered and expressed both gratitude that we were bringing it to light and interest in learning more about it.

**Barriers and Motivations for Behaviors and Behavior Change.**

Health behavior change theory is clear that simply increasing awareness and knowledge on a topic does not necessarily result in beneficial behavior changes. As a result, social marketing strategy uses identification and analysis of barriers and motivations for behaviors in conjunction with education and awareness building to encourage behavior change.

Cost is a major motivation for choices and a barrier for behavior changes. Our research confirms a great deal of previous research that garden location choices are made primarily as a result of cost, what land is free or donated, rather than with consideration of contaminant potential. Externally sourced materials also followed this trend of cost first choices. Our data showed that each different type of material is sourced from the cheapest location for that material. Mulch for example is sourced from the municipality or other businesses that provide it for free, while
manure most often came from an outside individual like a horse stables that was willing to give it away for free if the manager dealt with transportation.

Organizational capacity and structure at gardens had a large influence on all aspects of this issue. Managers regularly expressed they were unable to communicate with gardeners as much as they wanted (especially provide communications in different languages), do medium sized garden projects to improve the garden, or to use organic pest control methods instead of pesticides because they did not have enough help at the garden and their time and capacity was already stretched thin. The structure of how gardens managed and involved participants often resulted in high participant turnover, with some gardens having different participants each and every workday. This has ripple effects on everything from how contaminant information is communicated (you can’t rely on one time communications) to how individual behaviors are encouraged and enforced. With volunteer retention as a big concern, managers may shy away from contaminant education for fear of scaring people off. At the same time, managers must find ways to communicate concerns and enforce behaviors in a quick and repeatable way that is simple and clear, rather than maybe more in depth or long term education and behavior change strategies.

Finally, there are three situations where lack of awareness and lack of access to information and resources creates a barrier to staying safe from potential contaminant exposure. These are 1) lack of awareness of the land use history of the garden property and how to access that information, 2) lack of awareness of the lifecycle of sourced materials and inability to trace that lifecycle, and 3) confusion and lack of clear information on all aspects of soil testing for contaminants. In each of these situations, the largest barrier is the gardeners’ and managers’ inability to access information, even when they are aware of the issue and actively seek out the information. For example, many managers had looked into the land use history of their property but were unable to find or get access to the necessary information because it was not in official property records and individuals with memory of the area could not be found. In materials sourcing, managers were equally eager to trace the lifecycle and potential contamination pathways of the materials they were importing, but did not have the human resources to go down that rabbit hole of detective work necessary to understand this.
Communication Methods and Messaging

Modes of Communication.

Community-based social marketing emphasizes that the place where audience members encounter messaging - whether this is a physical location or simply a type of media - is important in determining their level of attention and engagement (Lee and Kotler, 2014). We found that the internet was a primary source of information for a majority of gardeners, meaning that internet-based messaging has social marketing potential for this audience.

To ensure access to our educational materials is convenient and welcoming to gardeners, it will be helpful to integrate them with existing trusted sources, whether online or in person. Lee and Kotler (2014) recommend distributing messaging through existing communication channels, as well as locating messaging where gardeners “hang out.” This involves placing materials physically within the gardens, as well as posting materials to garden websites and sharing them with Extension Offices, Master Gardener programs, and similar organizations.

Audience Segmentation.

Community gardens across the state are by no means homogenous. They differ in size, management structure, goals, and gardener background, to name just a few factors. For this reason, the best methods for communicating to these gardens - as well as the best behavior change strategies to promote - are likely to vary across gardens.

Since it would be beyond any single organization’s ability to tailor an outreach plan to each of the over 300 community gardens individually, we have designed a set of categories that can be used to group gardens according to relevant traits. We refer to this as our garden typology. Other typologies of community gardens have been created, but ours is the first to focus on gardens in North Carolina with special emphasis on contaminant exposure.

In initiating this study, we expected that the garden’s associated organization and its geographical location would be the biggest determinants of what contaminants were of concern, as well as the best ways to communicate with that garden. From our research, we have found that
neither of these is as significant a determinant as we expected, and organizing gardens into a typology based on these factors would not actually be possible or effective for our purposes. Instead, we organize gardens according to two factors: plot structure and demographics.

**Plot Structure.**

Generally, gardens could be categorized either as “assigned plot” or “communal” gardens. In gardens with assigned plots, individuals or families signed up with the garden management, often paying a yearly fee, to gain the rights to work and grow plants in a specific part of the garden. In communal gardens, individuals, families, or volunteer groups worked on garden-wide projects and tasks, either sharing the resulting produce amongst themselves or distributing it to a charitable organization.

This distinction is important in developing a communication strategy, because communication methods that work best for assigned plot gardens may not be effective for communal gardens. Assigned plot gardens are more likely to have long-term participants who are invested in the methods and practices used in their plots and those surrounding them. In-depth communications that establish trust and work to build solid positive habits may be ideal for these audiences. On the other hand, communal gardens are often visited by one-time volunteers or more casual participants, who have less of a personal investment in specific garden practices. For these groups, straightforward and attention-grabbing materials encouraging specific behaviors are more likely to be helpful.

This type of categorization is similar to that in the report by Drake and Lawson (2015), which separates gardens according to plot divisions. However, their paper includes a category representing a mixture between individual and communal plots, which we did not observe.

**Demographics.**

While all our case study gardens included a mixture of participant backgrounds and demographics, there are undoubtedly cases where gardens are skewed toward a certain age range, gender, education level, or race/ethnicity.
Our survey provided valuable insights on how we might segment our audience, given that different demographic groups displayed tendencies for different levels of knowledge, concern, and communications preferences.

- **OLDER PEOPLE** are more likely to have high knowledge about soil contaminants, get information from the internet, get information from garden organizations, and get information from a library.
- **MALES** are more likely to get information from a garden manager, and to get information from garden organizations.
- **MORE EDUCATED PEOPLE** are more likely to have high knowledge about pesticides, have high knowledge about soil contaminants, get their information from a library, and wash their hands frequently.
- **PEOPLE WITH CHILDREN IN THE HOUSEHOLD** are more likely to be concerned about soil contaminants, more likely to get information from the Internet, and more likely to get information from a garden manager.
- **PEOPLE WHO ARE NON-WHITE** (meaning they identified as a race other than white, or Spanish/Hispanic/Latino) are more likely to wash their produce frequently.

**Recommendations**

**DUSRC can help by providing education on:**

**General Awareness.**

While pesticides and their associated health implications are well understood and front of mind for community gardeners, soil contamination is not on gardeners’ mind and is often not understood. Educational resources and messaging should start at the beginning with this topic, helping gardeners understand what contaminants to be concerned about, where these contaminants may come from, and how they might be exposed to them. In these messages DUSRC should focus on “source oriented messaging” as our research found gardeners that were aware of contaminants had this awareness due to association with a material or source that it came from rather than as a result of their understanding or awareness of the contaminant itself.
Also, education and awareness building should use health focused messaging. This is a significant motivation across gardens we studied and studies show that positive framing around health topics are more effective in marketing organic products than negative framing (Gifford and Bernard, 2004).

**Awareness of Contamination in Mulch and Other Municipally-Sourced Materials.**

DUSRC can help gardens to understand the two key potential sources we identified - sourced materials and motor vehicles/roadways - by compiling what is important to know about these sources and by helping to fill in gaps in the presently available research. There is little to no literature on contamination potential in association with mulch, leaves or similar sourced materials. The lifecycle of these materials before they get to the garden should be researched and DUSRC should identify what if any are contaminant exposure pathways of concern for these materials. DUSRC should also particularly focus on municipally sourced materials and shed light on the lifecycle of these materials. Resources that educate gardeners on how to find information themselves about the specific materials they source would also be helpful. In the same sense, compilation of specific information on how nearby roadways, traffic, and roadway runoff may affect gardeners would be helpful as this was a commonly mentioned concern with a diverse set of potential pathways.

**Individual Behaviors.**

Individual Safety Behaviors are not used because 1) there is a lack of awareness of the value, and 2) there is a barrier of inconvenience and lack of urgency/apathy. The use of individual safety behaviors is the primary route through which gardeners are able to protect themselves from potential contaminant exposure risk while still getting to enjoy the benefits of community gardening. Therefore, in line with health behavior theory, DUSRC should elevate individuals’ awareness and sense of urgency related to why using these precautions are valuable and meaningful and what these practices are protecting them from.

**DUSRC can help by providing these educational resources and materials:**
DUSRC can offer major help to gardens by providing educational materials directly to managers, who can then distribute them to their gardeners as needed. We are confident there is a need for this, because we found that a major barrier to effective communications in many gardens is the lack of time and organizational capacity to create and distribute educational materials. Because of these limitations, DUSRC should avoid creating resources that put additional burden on managers to adapt and present. Instead, we recommend creating versatile resources that are ready for distribution, and do not require all gardeners to be in the same place at once. Examples of this type of communication include recorded video presentations, garden-specific forums, and other online resources. In gardens where internet use is limited, paper flyers may be helpful.

Additionally, in designing materials DUSRC should keep in mind that gardener turnover is high in many gardens, so in these contexts, a gardener is not likely to invest much energy in paying attention to garden messaging. To address this, we recommend that DUSRC put most of its resources into simple, efficient messaging that communicates the most important messages to short-term gardeners.

Since we have found that garden-level changes may be more effective in reducing contaminant exposure than individual-level changes, we suggest that DUSRC provide instructions on completing specific projects. Ideal projects will be those that can be made into workday events (which often garner high participation, if held infrequently), or can be carried out piece by piece by individual gardeners as they are available. Any project on a scale in between these is likely to have insufficient participation, placing the burden on garden managers to complete it.

Gardeners often trust organizations such as the Cooperative Extension Offices and the NCCGP, and get a significant amount of their gardening information from these sources. Therefore, we recommend that DUSRC partner with these organizations where possible, sharing and receiving informational resources, and encouraging these organizations to refer gardeners to DUSRC with questions about contamination.

Our survey findings allow us to begin segmenting our audience, offering suggestions for how to tailor communications to increase effectiveness. If DUSRC works closely with a garden, it is worth learning about gardener demographics for this reason. Below are our primary conclusions:
● If a garden is composed primarily of older members, we recommend focusing communications on the effects of contaminants and their remediation strategies, rather than explaining the nature of contaminants themselves. This is because we found that older gardeners tend to be more confident in their knowledge about contaminants.

● If a garden is composed largely of highly educated members, we recommend focusing communications on soil contaminants as opposed to pesticides, because higher education appears to be positively correlated with knowledge about the health impacts of pesticides, but there is no correlation with knowledge about soil contaminant impacts.

● If it is common within a garden for members to have children under 10 years old in their households, we recommend drawing direct connections between behaviors such as hand washing and reduced contaminant exposure, because these individuals already tended to be more concerned about the health impacts of soil contaminants.

DUSRC can help by providing other assistance, resources and guidance:

One of the large barriers to effectively limiting contaminant exposure and presence at gardens is the manager and gardeners’ lack of control over actions taken by nearby property owners or others on their same property. Lack of control is related to garden participants’ inability to effectively communicate with and leverage relationships with these neighboring parties. DUSRC can help gardens in this by providing resources for effective communication strategies, negotiation, and conflict resolution.

Soil testing is important but has many barriers. While DUSRC may be unable to provide testing itself, there are many things DUSRC can do to help make soil testing more accessible and more commonly used in gardens. First help gardeners understand that nutrient testing from the cooperative extension is not going to tell you everything you need to know about the health of your garden’s soils. The best way to do this may be by working with the extension offices directly as this is a commonly cited as a well trusted source of information and communications. Second, help connect people to testing resources. Many people asked for information on where to get contaminant testing so pointing to labs that will do testing, what testing they will do, and
the costs of that testing would be helpful. Finally, the most significant thing that DUSRC should research and provide expert information on is how to interpret soil testing results. What levels of different contaminants are safe and unsafe is hard to find online and at other trusted resources. This was the biggest educational/knowledge access issue reported to us.

Gardeners and managers struggle to get access to and understanding of the land use history of their property. DUSRC can help gardeners to understand where to go to learn about this (for example county records) and help gardeners to track down this information. Many times, official land use records did not have the information gardeners were looking for. DUSRC can help by providing guidance on where else to look for this information. Also, help gardeners to understand what to look for in land use history that may be of concern: what matters and what doesn’t when they are looking through these records and information.

Finally, DUSRC can provide information in different languages and help connect managers to resources for translation of their own materials. Overall helping gardens reduce language barrier through translation or non-language based messaging (infographics, etc.) would help gardens access and connect with a significant portion of their gardener population.

**Conclusion**

Community gardens have numerous benefits to those who work in and alongside them (Folstad et al. 201). However, the risk of contaminant exposure complicates these benefits for gardeners and recipients of garden produce. Garden managers and participants alike can minimize the likelihood of contaminant exposure through careful practices (US EPA 2011b), but in order to increase the prevalence of these practices, we needed to first understand what gardening behaviors are currently used across North Carolina, and why. For this reason, on behalf of the Duke University Superfund Research Center, we conducted a study that examines current community garden practices on management and individual levels, as well as barriers to behavior change and important communication methods. We employed mixed methods, including a web survey and six case studies at individual gardens.

We found that although North Carolina community gardens vary in their structure, purpose,
practices, and perspectives, we can draw several overarching conclusions to inform future communications and research. Based on the barriers, preferred communication methods, and information sources that our study revealed, we believe community gardeners would benefit from communication materials emphasizing big-picture contaminant risks, materials sourcing and lifecycle concepts, motor vehicles and roadway runoff effects, and finally safe versus unsafe levels of contaminant exposure. According to our findings, we also conclude that the best way to provide information to community gardeners is through the creation of ready-to-distribute materials, as well as instructions for garden-level projects, taking into consideration that materials should be tailored to different audiences and that garden-associated organizations will be key for the distribution and education to promote health protective behaviors and management choices.
Citations


Draper, Carrie, and Darcy Freedman. “Review and Analysis of the Benefits, Purposes, and Motivations Associated with Community Gardening in the United States.” *Journal of


Heiger-Bernays, W., A. Fraser, V. Burns, K. Diskin, D. Pierotti, K. Merchant-Borna, M. McClean, D. Brabander, and H. P. Hynes. “Characterization and Low-Cost Remediation of


https://www.thefreelibrary.com/Soil+lead+testing+at+a+high+spatial+resolution+in+an+urban+community...-a0464045509.


Oliver, Daniel G., Julianne M. Serovich, and Tina L. Mason. “Constraints and Opportunities with Interview Transcription: Towards Reflection in Qualitative Research.” *Social Forces; a Scientific Medium of Social Study and Interpretation* 84, no. 2 (December 2005): 1273–89.


Salido, Arthur L., Kelly L. Hasty, Jae-Min Lim, and David J. Butcher. “Phytoremediation of Arsenic and Lead in Contaminated Soil Using Chinese Brake Ferns (Pteris Vittata) and


Appendix A: Figures

Figure 1(a). Map of NCCGP-registered gardens.

Figure 1(b). Distribution of garden types according to NCCGP garden typology.

Figure 2. Outline of topical nodes.
Figure 3. Survey respondent gender and race distributions.
Figure 4. Level of education of survey respondents.

![Respondent Education Graph](image)

Figure 5. Level of difficulty in interpreting results of soil tests cited by managers on the survey.

![Interpreting Soil Test Results: Difficulty of Component Actions](image)
Figure 6. Number of mentions of individual health behaviors, from case study data.

![Individual Behaviors - Case Studies](image)

Figure 7. Self-assessed frequency of various individual safety behaviors, from survey data.

![Individual Behaviors - Survey](image)
Figure 8. Consumers of garden produce, according to garden managers, from survey data.

Consumers of Garden Produce

- Gardeners
- Friends and family
- Food banks
- School programs
- Local residents
- Other

Figure 9(a). Number of references to contaminant types in case study data, where statements were additionally coded as showing awareness or unawareness.

Awareness by Type of Contaminant

- AWARE
- UNAWARE
Figure 9(b). Number of references to contaminant types in case study data (alternate visualization).

171 Total References
Figure 10. Motivations behind community gardening, from case study data.

Motivations for gardening/gardening choices

- Community Engagement
- Food Security
- Health
- Money
- Prefer Natural/Organic
- Reduce Pathogens
- Save Water
- Soil Health

Figure 11. Motivations behind community garden participation, from survey data.

Motivations for Gardening

<table>
<thead>
<tr>
<th>Percentage of Respondents</th>
<th>Other</th>
<th>Time outside</th>
<th>Physical activity</th>
<th>Socialize</th>
<th>Nature</th>
<th>Feed family</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>60</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>60</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>60</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>60</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>
Figure 12. Justification by managers for not testing garden soil, from survey data.

Reasons for Not Testing Soil

- Contamination not a concern: 44%
- It had not occurred to us: 8%
- Testing is too expensive: 10%
- Not sure how to test: 18%
- Could not find a lab: 9%
- Concerned about liability: 11%
- Other: 4%

Figure 13(a). Number of coding instances of different communication methods, from case study data.

Method of Communication

- Signage: 44%
- Newsletter: 11%
- Email: 9%
- Social Media: 18%
- Other: 10%
Figure 13(b). Number of coding instances of different information sources, from case study data.

Figure 14. Commonly used sources of contaminant/pesticide information, from survey data.
Figure 15. Number of gardens with observed potential external sources of contaminants, from site visit observation photos and checklists.
Appendix B: Case Study Garden Descriptions

County Garden

Type: A neighborhood/public garden divided into plots. Each garden bed or plot is rented on a yearly basis to an individual or family. Each member decides what to plant and how to manage their rented space.

Structure: Managed by the county’s cooperative extension. In addition to the garden manager, they have developed a leadership team that consists of nine long-time experienced gardeners. The team helps making decisions related with day to day management. They help other gardeners and create a stronger community (MGIGT).

Garden’s intent, primary goals: Started as a donation/service garden. Initially the space was managed as a cooperative garden, growing food for those in need in the community. However, the purpose evolved into providing opportunities for people to garden and produce their own food (MGIGT). The garden kept the requirement/rule of donating 10% of their harvest to alleviate food insecurity (MGIKT).

Location: Garden is located at the agricultural extension office, on the edge of a parking lot, surrounded on all other sides by dense forest. Beyond the forest is a large highway interchange, and the garden is surrounded on all sides by heavy traffic roads within 500 feet. It is directly adjacent to semi-industrial buildings, from school buildings to quarries to neighborhoods, with forest land, commercial retailers, and more in the 1 mile radius.

Participants: Community garden members are mostly families, some with children. Approximately 70% of the garden members are middle-aged or older, with a smaller representation of younger and older generations (MGFGT, MGIKT). Demographics represented include African Americans, Caucasians, and a few families from Sudan and Burma (MGIGT, MGIKT). Of the 18 members that attended the focus group, 10 self-identified as master gardeners and all of them had more than 5 years of general experience gardening (MGFGT).
Church Garden

**Type:** A neighborhood/public garden and a cooperative garden. All members participate in the planting and maintenance of shared garden plots and the harvests are shared equally.

**Structure:** The current location is sponsored by a faith-based organization. However, the community garden is not part of the church, and all garden business is independent of it. The garden is managed by a four individuals, three of whom are directly involved with gardening activities, and one of whom focuses on the logistics and accounting.

**Garden’s intent, primary goals:** The main purpose is to provide space for community members to grow their own food. They also hope to begin donating 10% of their total harvest to disadvantaged communities. They intend to become more inclusive, reaching out to low income neighborhoods and senior citizens (GGITT, GGIMT).

**Location:** Established originally in 2010, but moved to current location in 2016. Located on church property in a neighborhood area, and has low-traffic roads on two sides, right up to the edge of the garden. Mostly surrounded by apartments, schools and churches for about a mile in all directions, except for the northeast. There is a multi-lane highway about half a mile north and northeast surrounded by shopping centers, gas stations, and commercial sites. The majority of the buildings and houses surrounding the land are old, potentially pre-1978 (GGFGT, google maps). Approximately one mile north is a manufacturing area, mostly construction supply, metal processing, gas plants, vehicles, etcetera.

**Participants:** Roughly 15 individuals consistently involved with garden activities. Participants are mostly families, some of whom bring their children regularly. Most participants are within the 30-60 age range, but there are a few very active older gardeners. The majority of the garden participants are Caucasian (GGITT, GGIFG). Occasionally there are also larger volunteering groups that come to the garden working days, such as boy scouts and girl scouts, church groups, elementary school groups. Four of the twelve gardeners that participated in the focus group highlighted their undergraduate education as an influence on their general knowledge and interest in gardening.
**Refugee Garden**

**Type:** A neighborhood/public garden. Every family or garden member has their own assigned plot from which they harvest their selection of produce.

**Structure:** The garden founder oversees management, accounting, and communication. A few garden members, including the manager, are affiliated with the church in some capacity. However, the garden is independent of this faith-based organization.

**Garden’s intent, primary goals:** The goal of this garden is to “develop a new model for creating sustainable community gardens with community placemaking features”. It was created with the main purpose of providing the nearby Burmese refugee population with a place to garden.

**Location:** Immediate surroundings are a neighborhood built around the 1950s-60s. About one mile from the garden on all sides, except to the west, are heavily concentrated industrial and commercial land uses bordering to major multi-lane highways.

**Participants:** Primarily Burmese refugees. However, there are also non-Burmese members that live nearby the garden and/or are affiliated with the church.

**Medical Garden**

**Type:** A medical/therapeutic garden. Plots are gardened by volunteer groups, and produce is provided free of cost to patients at the associated clinic.

**Structure:** Owned and managed by the associated clinic. Gardening is overseen by a dedicated member of clinic staff, with help from various long-term volunteers.

**Garden’s intent, primary goals:** The primary goal is to provide healthy food to patients, many of whom ordinarily lack access to fresh produce. The secondary goal is to educate patients on gardening and preparing healthy food.

**Location:** The garden is directly beside the clinic, and is close to several moderately busy roads. It is surrounded on most sides by residences, and is within one mile of a dry cleaning facility, as
well as several other commercial areas.

**Participants:** In addition to the long-term volunteers who work in the garden, most work is done by volunteer groups, including church groups, school clubs, and Eagle Scouts.

**School Garden**

**Type:** Associated with a religious school for elementary-aged children, but primarily targeted towards neighborhood residents.

**Structure:** Owned and managed by a church-based school. Two instructors at the school take primary responsibility for organizing garden tasks.

**Garden’s intent, primary goals:** The main goal is to educate and train the local community to garden, building their marketable skills and reinforcing the local economy. Secondarily, the garden seeks to connect students with the food system.

**Location:** The garden is behind the school, though managers intend to add plots in front of the school as well. Current plots are not directly adjacent to any major roads, but there are fences and structures on all sides, and a nearby electric substation. School was built in the early 1900s.

**Participants:** Three to four volunteer participants garden on a regular basis. Children from the school periodically help, primarily to harvest produce.

**City Garden**

**Type:** A neighborhood/public garden associated with a church.

**Structure:** A community group led by seven to eight leadership team members. Although the garden is on church land and receives resources from the church, it considers itself largely independent, and welcomes gardeners from outside the church.

**Garden’s intent, primary goals:** The main goal is to build community engagement and create a sense of togetherness for the enjoyment of the members. The garden donates most of its produce to a charitable organization with the intention of providing healthy food for food-insecure
populations.

**Location:** The garden is in the middle of a city block, though the surrounding area is only moderately urban; buildings are generally no more than three stories, and there is significant green space. Residences are interspersed with businesses. The garden is set back from all nearby roads, with buildings on all sides.

**Participants:** Gardeners are generally local residents, though many live beyond walking distance from the garden. Many seem to be involved with the garden because of personal connections with current gardeners.
# Appendix C: Node Structure

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Awareness of Risk</strong></td>
<td>Overall understanding and familiarity with contaminants and different potential risks in the garden</td>
</tr>
<tr>
<td>Aware</td>
<td></td>
</tr>
<tr>
<td>Unaware</td>
<td></td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td>Potential factors that could stop gardens/gardeners from being able to implement behavior or management choice changes that will reduce contaminant exposure. Also things that limit the gardens/gardeners' ability to educate on this topic</td>
</tr>
<tr>
<td>Apathy</td>
<td>Lack of concern, sense of urgency or laziness</td>
</tr>
<tr>
<td>Cost</td>
<td>Monetary limitations</td>
</tr>
<tr>
<td>Fear</td>
<td></td>
</tr>
<tr>
<td><strong>Human Resources</strong></td>
<td>Not having enough human resources. For instance, lack of translator, lack of consistent volunteers (engagement)</td>
</tr>
<tr>
<td>Lack of Publication</td>
<td>Availability of information is limited or access to information is limited</td>
</tr>
<tr>
<td>Physical Limitations</td>
<td>Any potential barrier related to garden location, structure, or infrastructure that cannot be changed</td>
</tr>
<tr>
<td>Relationships</td>
<td>Social capital or connections. For example if you don't know the person in the plot next to you and/or you have a bad relationship with your neighbors</td>
</tr>
<tr>
<td>Time</td>
<td><strong>Contaminants</strong></td>
</tr>
<tr>
<td>------</td>
<td>-----------------</td>
</tr>
<tr>
<td></td>
<td>Mention/reference/observation on any of the pollutants or substances of interest for our study that could potentially harm the health of community gardeners</td>
</tr>
<tr>
<td>Arsenic</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td></td>
</tr>
<tr>
<td>Heavy Metals</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td></td>
</tr>
<tr>
<td>Other Contaminants</td>
<td>A known contaminant that is not one of our &quot;top 10&quot; but is named/obvious</td>
</tr>
<tr>
<td>Pathogens</td>
<td></td>
</tr>
<tr>
<td>Potential Unknown</td>
<td>Any reference to a potential contaminant and/or potential source of contamination unknown for the research team (i.e. mention to soil brought from unknown site)</td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>Nearby or on site agriculture, current or former agriculture</td>
</tr>
<tr>
<td>Category</td>
<td>Example</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Dry Cleaners</td>
<td></td>
</tr>
<tr>
<td>Motor Vehicles</td>
<td>Public roads nearby, especially those with heavy traffic (i.e. mention or observations of large trucks, parking lots)</td>
</tr>
<tr>
<td>Nearby Industrial Commercial</td>
<td>Close industrial or commercial site</td>
</tr>
<tr>
<td>Old Buildings</td>
<td>Buildings pre-1978</td>
</tr>
<tr>
<td>Other</td>
<td>Any other external source that is out of the control of the gardeners/managers that causes potential contamination to the garden/ers</td>
</tr>
<tr>
<td>Power Plants</td>
<td>For example, coal-fired powerplants</td>
</tr>
<tr>
<td>Institutions and Structure</td>
<td>Sets of informal and formal norms which govern the practices and potentially the external sources of contaminants relevant to the garden</td>
</tr>
<tr>
<td>Internal Institutions</td>
<td>Some of them can be rules, application processes, and management team structure. Basically any structure or system of how the garden functions and is set up</td>
</tr>
<tr>
<td>External Institutions</td>
<td>Rules, relationships, structures, etc. that are imposed from outside the garden</td>
</tr>
<tr>
<td>Knowledge Inaccuracy</td>
<td>Any instance where the gardeners’ knowledge is inaccurate/incorrect or not founded in the scientific literature</td>
</tr>
<tr>
<td>Materials in Garden</td>
<td>Materials that may be present in the garden because of management choices</td>
</tr>
</tbody>
</table>

- Cardboard or Newspaper
- Coffee Grounds
<table>
<thead>
<tr>
<th>Materials</th>
<th>Sourcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost</td>
<td></td>
</tr>
<tr>
<td>Hay</td>
<td>Straw or hay</td>
</tr>
<tr>
<td>Leaves</td>
<td></td>
</tr>
<tr>
<td>Manure</td>
<td>Horse, turkey, chicken, cow, etc.</td>
</tr>
<tr>
<td>Mulch</td>
<td>From woodchips, among others.</td>
</tr>
<tr>
<td>Railroad Ties</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td></td>
</tr>
<tr>
<td>Tools</td>
<td></td>
</tr>
<tr>
<td>Treated Wood</td>
<td>Any mention of treated wood regardless of the year this material was</td>
</tr>
<tr>
<td></td>
<td>sourced</td>
</tr>
<tr>
<td><strong>Materials Sourcing</strong></td>
<td>Potential sources of materials present in the garden</td>
</tr>
<tr>
<td>Business</td>
<td></td>
</tr>
<tr>
<td>From within the</td>
<td></td>
</tr>
<tr>
<td>garden</td>
<td></td>
</tr>
<tr>
<td>Gardener's home</td>
<td></td>
</tr>
<tr>
<td>Municipal or City</td>
<td></td>
</tr>
<tr>
<td>Other Individual or</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td></td>
</tr>
<tr>
<td>Method of Communication</td>
<td>Motivations</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Email</td>
<td>Any mention of what motivates gardeners and garden managers in general (values, goals, reasons). It could refer for instance to what motivates people to be part of the community garden or something specific as what motivates the garden manager for the adoption of a certain management practice (i.e. water collection system)</td>
</tr>
<tr>
<td>Newsletter</td>
<td></td>
</tr>
<tr>
<td>Signage</td>
<td></td>
</tr>
<tr>
<td>Social Media</td>
<td></td>
</tr>
<tr>
<td>Word of Mouth</td>
<td></td>
</tr>
<tr>
<td>Workshops</td>
<td></td>
</tr>
</tbody>
</table>

Community Engagement
Food Security
Health
Money
Prefer Natural/Organic

Mentions of individuals caring about the quality of the food, lack of chemicals, food safety, etc.
| Reduce Pathogens |  |
| Save Water |  |
| Soil Health | Refers to the motivation of improve/maintain the soil's ability to produce healthy plants |

**Practices**

Covers all practices from management choices to individual behaviors

<p>| Cap Soil |  |
| Chemical Fertilizers | Use or refusal to use chemical fertilizers [Child nodes: Use and Don't Use] |
| Children in garden | Presence of children in the garden |
| Gloves | Use or non-use of gloves while gardening [Child node: No gloves] |
| Label Reading | Reading labels on products in order to correctly use them in the safest way |
| Pesticides | Use of pesticides in the garden by the gardeners or managers. Everywhere in this node structure when we say &quot;pesticide&quot; we mean synthetic pesticides (not organic, or natural pesticide products).[Child nodes: Use, Don't Use and Integrative Pest Management] |
| Plant Location and Type | Where gardeners/garden managers choose to plant vegetables and what vegetables they chose to grow |
| Produce Cleaning | Individual action to clean produce [Child nodes: Peel Produce and Wash Produce] |
| Raised Beds |  |</p>
<table>
<thead>
<tr>
<th>Soil or Water Testing</th>
<th>If the gardeners or managers have done testing of their soil or water at any point, or if they specifically mention they have NOT done testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash Hands</td>
<td>Individual action performed in garden or after gardening [Child nodes: Wash and Don't Wash]</td>
</tr>
<tr>
<td>Wash or Remove Clothing</td>
<td>Mention of individual action performed before/upon entering household</td>
</tr>
<tr>
<td>Wash Tools</td>
<td>Individual action, cleaning tools that are used in the garden</td>
</tr>
<tr>
<td>Water Collection</td>
<td>For example, rainwater collection system</td>
</tr>
<tr>
<td><strong>Sources of Information</strong></td>
<td>Mentions on sources of information done by community gardeners or garden managers</td>
</tr>
<tr>
<td>Academic Institution or Resources</td>
<td>University resources for instance</td>
</tr>
<tr>
<td>Books</td>
<td></td>
</tr>
<tr>
<td>Coop Extension</td>
<td></td>
</tr>
<tr>
<td>Garden Associated Institution</td>
<td>Some examples could be arboretum, nursery, NCCGP, state fair, among others</td>
</tr>
<tr>
<td>Leadership</td>
<td></td>
</tr>
<tr>
<td>Online</td>
<td></td>
</tr>
<tr>
<td>Other Gardeners</td>
<td></td>
</tr>
<tr>
<td>Personal Knowledge</td>
<td></td>
</tr>
</tbody>
</table>
Appendix D: Regression Analysis

After performing a series of statistical analysis, we selected the models that presented more conceptual and statistical significance for our research questions. For all the models, we used the variables shown in Table 1. The High Response Garden variable was generated after noticing that we had a disproportionate amount of respondents from this location.

Table 1 Variables for quantitative analysis: multiple linear regressions

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable Name</th>
<th>Type of Data</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ksoil</td>
<td>Knowledge of Soil Health Impacts</td>
<td>Ordered Categorical</td>
<td>The respondent’s self-assessed level of knowledge about the health impacts of contaminants in garden soil</td>
</tr>
<tr>
<td>Consoil</td>
<td>Concern about Soil Health Impacts</td>
<td>Ordered Categorical</td>
<td>The respondent’s self-assessed level of concern about the health impacts of contaminants in garden soil</td>
</tr>
<tr>
<td>Kpest</td>
<td>Knowledge of Pesticide Health Impacts</td>
<td>Ordered Categorical</td>
<td>The respondent’s self-assessed level of knowledge about the health impacts of pesticides and herbicides in the garden</td>
</tr>
<tr>
<td>Con_apppest</td>
<td>Concern about Pesticide Application Health Impacts</td>
<td>Ordered Categorical</td>
<td>The respondent’s self-assessed level of concern about the health impacts of contact with pesticides while applying them</td>
</tr>
<tr>
<td>Conpest</td>
<td>Concern about Pesticides on Food Health Impacts</td>
<td>Ordered Categorical</td>
<td>The respondent’s self-assessed level of concern about the health impacts of pesticides on the foods they eat</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------------------------</td>
<td>---------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Age</td>
<td>Respondent Age</td>
<td>Continuous</td>
<td>Self-reported age</td>
</tr>
<tr>
<td>Educ</td>
<td>Respondent Education</td>
<td>Ordered Categorical</td>
<td>Highest level of education completed: Less than high school, high school degree, some college, associate degree, bachelor’s degree, master’s degree, professional degree</td>
</tr>
<tr>
<td>Male</td>
<td>Respondent Gender</td>
<td>Binomial</td>
<td>Self-identified gender (all respondents selected either male or female though a third option was provided)</td>
</tr>
<tr>
<td>Non_white</td>
<td>Respondent Race/Ethnicity</td>
<td>Unordered Categorical</td>
<td>Any respondent who identified with at least one race other than white, and/or a Spanish, Hispanic, or Latino ethnicity, was coded as “non-white”</td>
</tr>
<tr>
<td>High Response Garden</td>
<td>Participant at County Garden</td>
<td>Binomial</td>
<td>Any respondent from County Garden was assigned to this category, because a disproportionate number of those gardeners took the survey</td>
</tr>
</tbody>
</table>
Motivation

Unordered Categorical

Motivations cited by respondents for their own participation in the garden: helping feed family, spending time outside, being active, socializing, getting in touch with nature, and “other”

| Children_household | Respondent Children in Household | Binomial | Whether the respondent had one or more children under the age of 10 years old living in their household |

We performed a series of multiple linear regressions to model the relationship between two or more explanatory variables and our response variables: knowledge of health impacts of soil contaminants and pesticides, concern of health impacts of soil contaminants and pesticides, preferred sources of information, frequency of individual behaviors such as washing hands, washing produce and the use of protective equipment.

For the knowledge and concern regressions, we used ordered logistic regression models and we interpreted the results in terms of proportional odds ratios. Odds ratio is a measure of association between an exposure and an outcome. This option makes the interpretation of the coefficients easier since it allows us to compare the outcome given a particular explanatory variable, compared to the odds of the outcome occurring in the absence of it.

**KNOWLEDGE OF GARDENERS: SOIL CONTAMINANTS**

To find out the factors that seem to influence how much gardeners know about health impacts of soil contamination, we used an ordered logistic regression using the following variables:

Response: level of knowledge about contaminants

Predictors: age, education, gender, race and/or ethnicity, level of concern about health impacts of...
soil contamination, high response garden dummy variable.

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=</td>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Pseudo R2</td>
<td>0.1139</td>
<td></td>
</tr>
</tbody>
</table>

Knowledge of soil health

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age*</td>
<td>1.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Education*</td>
<td>0.62</td>
<td>0.03</td>
</tr>
<tr>
<td>High Response Garden*</td>
<td>3.69</td>
<td>0.39</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>0.857</td>
<td>0.64</td>
</tr>
<tr>
<td>Race and/or ethnicity*</td>
<td>1.84</td>
<td>0.01</td>
</tr>
<tr>
<td>Concern soil health</td>
<td>0.87</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Estimates significant at \( \alpha \)-level 0.01

The odds of being in a higher category of knowledge is 1.06 higher when age increases by one unit. The odds of knowing more about soil health increases by 0.62 with a higher level of education, is 1.84 higher for the non-white gardeners.

The variables in the model are independent and there is no high correlation between them. We ran the proportional odds test (omodel). With a Prob\( >\)chi2 of 0.1045 we prove that this assumption has not been violated. However, the education and age coefficients may be different within categories of knowledge.

**KNOWLEDGE OF GARDENERS: PESTICIDES**
To find out the factors that seem to influence how much gardeners know about health impacts of pesticides, we used an ordered logistic regression using the following variables:

Response: level of knowledge about health impacts of pesticides

Predictors: age, education, gender, race and/or ethnicity, level of concern about health impacts of pesticide application and pesticides on food, and a high response garden dummy variable.

<table>
<thead>
<tr>
<th>N=</th>
<th>69</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudo R2</td>
<td>0.0633</td>
</tr>
</tbody>
</table>

### Knowledge of Pesticides

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education**</td>
<td>0.636</td>
<td>0.13</td>
</tr>
<tr>
<td>Age</td>
<td>1.026</td>
<td>0.0244</td>
</tr>
<tr>
<td>High Response Garden</td>
<td>1.164</td>
<td>0.15</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>1.069</td>
<td>0.68</td>
</tr>
<tr>
<td>Race and/or ethnicity</td>
<td>1.293</td>
<td>0.64</td>
</tr>
<tr>
<td>Concern pesticide application</td>
<td>0.72</td>
<td>0.13</td>
</tr>
<tr>
<td>Concern pesticides in food*</td>
<td>4.287</td>
<td>1.28</td>
</tr>
</tbody>
</table>

*Estimates significant at α-level 0.01
**Estimates significant at α-level 0.05

The odds of being in a higher category of knowledge is 0.64 higher with a higher level of
education. The odds of knowing more about health impacts of pesticides are 4.29 higher when respondents have a higher concern of pesticides in food.

The variables in the model are independent and there is no high correlation between them. We ran the proportional odds test (omodel). With a Prob>chi2 of 0.6409 we prove that this assumption has not been violated. However, concern about the application of pesticides may be different within categories of knowledge.

CONCERNS ABOUT HEALTH IMPACTS: SOIL CONTAMINANTS

To determine the factors that influence how much gardeners are concerned about health impacts of soil contaminants, we ran an ordered logistic regression using the following variables:

Response variable: Concern about health impacts of soil contaminants

Predictors: age, gender, race/ethnicity, education, children in household, level of knowledge about contamination, motivation for gardening

<table>
<thead>
<tr>
<th>Concerns about soil contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanatory variables</td>
</tr>
<tr>
<td>Children in Household*</td>
</tr>
<tr>
<td>Knowledge Soil Contamination*</td>
</tr>
<tr>
<td>Education Bachelors*</td>
</tr>
<tr>
<td>Education Masters or PHD*</td>
</tr>
</tbody>
</table>

N= 63
Pseudo R2 = 0.0995
The odds of being more concerned is 1.29 higher for gardeners that know more about soil contamination. Education is also positively correlated with concern. Having a bachelor’s degree increases the odds of being more concerned by 3.35, and having a masters or PHD increases the odds by 1.31. In addition, the odds of being more concerned also increases by 1.44 if one of the gardeners’ motivations is feeding the family and by 0.82 if they are non-white.

The variables in the model are independent and there is no high correlation between them. We ran the proportional odds test (omodel). With a Prob>chi2 of 0.1972 we prove that this assumption has not been violated. However, the dummy variable that indicates those respondents with children in the household may be different within categories of concern.

**CONCERNS ABOUT HEALTH IMPACTS: PESTICIDES APPLICATION**

To determine the factors that influence how much gardeners are concerned about health impacts of the application of pesticides, we ran an ordered logistic regression using the following variables:

Response variable: Concern about health impacts of pesticides

Predictors: age, gender, race/ethnicity, education, children in household, level of knowledge about contamination, motivation for feeding family, concerns about pesticides on food and a high response garden dummy.
The odds of being more concerned is 1.99 higher for gardeners that know more about pesticides. The odds of being more concerned about the application of pesticides increases by 10.45 when gardeners are also concerned about health impacts of pesticides in their food.

To have values in all categories of our response variable (concern of application of pesticides) we reduced the groups to only two: “none or somewhat concerned” and “very concerned”. Therefore,
there is no need of running the proportional odds test.

**SOURCES OF INFORMATION**

For each of the sources of information we ran logistic regressions using education, age, gender, race and/or ethnicity, respondents with children in the household and clustering for the high response garden.

<table>
<thead>
<tr>
<th>N=</th>
<th>71</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudo R2</td>
<td>0.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Internet</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanatory variables</td>
<td>Odds Ratio</td>
<td>Std Error</td>
</tr>
<tr>
<td>Education</td>
<td>1.24</td>
<td>0.12</td>
</tr>
<tr>
<td>Age*</td>
<td>0.95</td>
<td>0.00</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>0.79</td>
<td>0.69</td>
</tr>
<tr>
<td>Race and/or ethnicity*</td>
<td>0.69</td>
<td>0.06</td>
</tr>
<tr>
<td>Children in household*</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>High Response Garden</td>
<td>0.92</td>
<td>0.08</td>
</tr>
</tbody>
</table>

*Estimates significant at α-level 0.01

<table>
<thead>
<tr>
<th>N=</th>
<th>71</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudo R2</td>
<td>0.03</td>
</tr>
</tbody>
</table>
### Gardeners

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>1.02</td>
<td>0.046</td>
</tr>
<tr>
<td>Age</td>
<td>1.006</td>
<td>0.00</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>0.489</td>
<td>0.15</td>
</tr>
<tr>
<td>Race and/or ethnicity</td>
<td>2.38</td>
<td>0.57</td>
</tr>
<tr>
<td>Children in household</td>
<td>1.54</td>
<td>0.15</td>
</tr>
<tr>
<td>High Response Garden</td>
<td>1.37</td>
<td>0.11</td>
</tr>
</tbody>
</table>

*N= 71

Pseudo R2 = 0.16

*Estimates significant at α-level 0.01

**Estimates significant at α-level 0.05

***Estimates significant at α-level 0.1

### Manager

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education*</td>
<td>1.41</td>
<td>0.07</td>
</tr>
<tr>
<td>Age*</td>
<td>0.98</td>
<td>0.00</td>
</tr>
<tr>
<td>Gender (male)*</td>
<td>0.11</td>
<td>0.08</td>
</tr>
<tr>
<td>---------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Race and/or ethnicity***</td>
<td>2.62</td>
<td>1.46</td>
</tr>
<tr>
<td>Children in household *</td>
<td>10.41</td>
<td>4.14</td>
</tr>
<tr>
<td>High Response Garden***</td>
<td>1.37</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*N = 71

<table>
<thead>
<tr>
<th>Pseudo R2</th>
<th>0.12</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>0.97</td>
<td>0.06</td>
</tr>
<tr>
<td>Age**</td>
<td>1.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Gender (male)*</td>
<td>0.201</td>
<td>0.10</td>
</tr>
<tr>
<td>Race and/or ethnicity</td>
<td>1.32</td>
<td>0.86</td>
</tr>
<tr>
<td>Children in household *</td>
<td>0.51</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*Estimates significant at α-level 0.01

***Estimates significant at α-level 0.1
**FREQUENCY OF WASHING HANDS, PRODUCE AND USING PROTECTIVE EQUIPMENT**

To find out the factors that seem to influence how much gardeners wash their hands, their produce and use protective equipment, we used an ordered logistic regression using the following variables:
Responses: frequency of washing hands, then frequency of washing produce and finally the use of protective equipment.

Predictors: age, education, gender, race and/or ethnicity, level of concern about health impacts of soil contaminants, pesticide application and pesticides in food, knowledge of health impacts and high response garden dummy variable.

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education *</td>
<td>0.88</td>
<td>0.019</td>
</tr>
<tr>
<td>High Response Garden</td>
<td>1.30</td>
<td>0.022</td>
</tr>
<tr>
<td>Concern pesticides in food*</td>
<td>3.97</td>
<td>0.92</td>
</tr>
<tr>
<td>Concern application pesticides*</td>
<td>0.32</td>
<td>0.07</td>
</tr>
<tr>
<td>Concern soil contaminants*</td>
<td>0.54</td>
<td>0.05</td>
</tr>
<tr>
<td>Age</td>
<td>1.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Race and/or ethnicity</td>
<td>1.44</td>
<td>0.19</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>0.77</td>
<td>0.55</td>
</tr>
<tr>
<td>Knowledge pesticides</td>
<td>0.61</td>
<td>0.17</td>
</tr>
<tr>
<td>Knowledge soil contaminants</td>
<td>0.85</td>
<td>0.22</td>
</tr>
</tbody>
</table>
*Estimates significant at α-level 0.01

The odds of increasing the frequency of washing hands is 3.97 higher when gardeners are more concerned about pesticides in food, 0.32 higher when they are concerned about pesticide application and 0.54 higher when they are concerned about soil contamination effects on health. Being non-white and a male also increases the odds of increasing the frequency of washing hands.

The variables in the model are independent and there is no high correlation between them. We ran the proportional odds test (omodel). With a Prob>chi2 of 0.03 there may be a violation of the assumption of proportional odds for different categories in the frequency of washing hands.

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>0.96</td>
<td>0.27</td>
</tr>
<tr>
<td>High Response Garden</td>
<td>0.64</td>
<td>0.44</td>
</tr>
<tr>
<td>Concern pesticides in food*</td>
<td>0.68</td>
<td>0.10</td>
</tr>
<tr>
<td>Concern application pesticides</td>
<td>1.05</td>
<td>2.61</td>
</tr>
<tr>
<td>Concern soil contaminants</td>
<td>0.17</td>
<td>0.28</td>
</tr>
<tr>
<td>Age*</td>
<td>0.98</td>
<td>0.00</td>
</tr>
<tr>
<td>Race and/or ethnicity</td>
<td>0.17</td>
<td>0.00</td>
</tr>
</tbody>
</table>

n= 55
Gender (male) | 0.36 | 0.07
Knowledge pesticides | 0.95 | 0.56
Knowledge soil contaminants | 0.74 | 0.27

*Estimates significant at α-level 0.01

The variables in the model are independent and there is no high correlation between them. We ran the proportional odds test (omodel). With a Prob>chi2 of 0.1697, we prove that this assumption has not been violated. However, the dummy variable that indicates the race/ethnicity dummy that indicates its relationship with the frequency of washing produce may be different within frequency of washing produce categories.

| N= | 55 |

**PROTECTIVE EQUIPMENT**

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Odds Ratio</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>0.771</td>
<td>0.129</td>
</tr>
<tr>
<td>High Response Garden**</td>
<td>0.196</td>
<td>0.127</td>
</tr>
<tr>
<td>Concern pesticides in food**</td>
<td>5.78</td>
<td>4.40</td>
</tr>
<tr>
<td>Concern application pesticides*</td>
<td>2.368</td>
<td>0.28</td>
</tr>
<tr>
<td>Concern soil contaminants*</td>
<td>0.357</td>
<td>0.08</td>
</tr>
<tr>
<td>Age</td>
<td>1.023</td>
<td>0.03</td>
</tr>
<tr>
<td>Variable</td>
<td>Coefficient</td>
<td>SE</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------------</td>
<td>-----</td>
</tr>
<tr>
<td>Race and/or ethnicity</td>
<td>1.241</td>
<td>0.41</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>0.92</td>
<td>0.77</td>
</tr>
<tr>
<td>Knowledge pesticides*</td>
<td>2.418</td>
<td>0.07</td>
</tr>
<tr>
<td>Knowledge soil contaminants**</td>
<td>0.627</td>
<td>0.10</td>
</tr>
</tbody>
</table>

*Estimates significant at α-level 0.01  
**Estimates significant at α-level 0.05

The variables in the model are independent and there is no high correlation between them. We ran the proportional odds test (omodel). With a Prob>chi2 of 0.084, we prove that this assumption has not been violated. However, the dummy variable that indicates the race/ethnicity dummy that indicates its relationship with the frequency of washing produce may be different within frequency of using protective equipment.