EXECUTIVE SUMMARY:

UNDERSTANDING PATHWAYS TO CONTAMINANT EXPOSURE IN NORTH CAROLINA'S COMMUNITY GARDENS

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I. INTRODUCTION

Urban agriculture and community gardens are a valuable resource for promoting health while building community bonds. They can even be a means to increase the wellbeing of vulnerable communities by reducing food insecurity, providing opportunities for outdoor exercise, social interaction, and increasing property values. Unfortunately, community gardens are often limited by available physical and human resources, resulting in choices that can potentially put gardeners at a higher risk of exposure to contaminants, whether from the soil at garden sites or through pesticide usage. There are three major factors that can result in the presence of contaminants and subsequent exposure on a garden site: i) the site's history and surrounding land uses; ii) land management practices in the garden; and iii) community gardeners' lack of knowledge and/or risky behaviors. There are, however, an equal number of practices that managers and gardeners can employ to reduce the potential for exposure to contaminants. With proper understanding of potential risks, and the resulting behavior changes by managers and gardeners, it is possible to continue to enjoy the many benefits of community gardening while avoiding the negative impacts of potential contaminant exposure in the garden environment.

The Duke University Superfund Research Center (DUSRC) completed a one-year research project with three Masters students at the Nicholas School of the Environment at Duke University to explore these issues in the context of North Carolina community gardens. This project applied a mixed-methods approach to study the extent to which community gardeners currently understand this issue and employ practices that reduce exposure, as well as the barriers and motivations for reducing contamination and exposure through behavior change. Methods included distribution of a statewide survey by email and online (150 total responses), complemented with visits to six gardens across the state where interviews, focus groups, and observations were conducted (Figure 1).

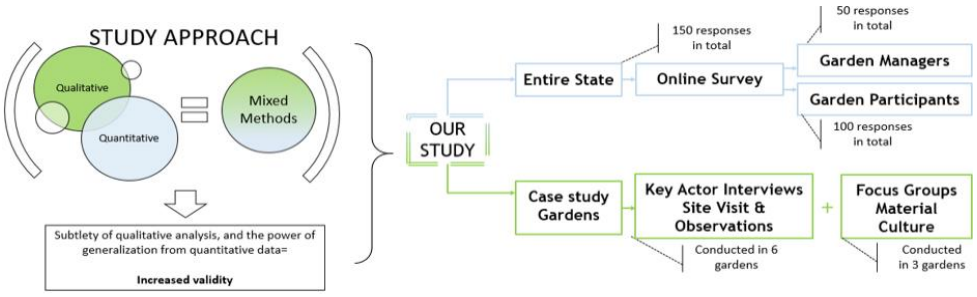

Figure 1: Master's Project mixed methods research design.

This research will ultimately inform a five-year project in partnership with gardening organizations and gardens to continue learning about these issues and to encourage education, awareness, safe behaviors, and remediation across the state. If you or your garden are interested in learning more or getting involved, please feel free to get in touch with the Duke Superfund Research Center (see contact information at the end of this document).

This report summarizes our most relevant findings and is organized as follows:

- Section II provides information on our findings related to the contaminants most likely to be of concern for community gardeners and the most common sources.
- Section III summarizes the most common ways in which community gardeners might be exposed to contaminants and some of the most effective measure to prevent those exposures.
- Section IV discusses our results related to the awareness that community gardeners have about types and sources of contaminants and potential motivations for and barriers to engaging in behaviors that reduce the risk of exposure.
- Section V focuses on the most effective communication and outreach messages, methods and channels for increasing the awareness and impacting the behavior to reduce exposures of community gardeners in North Carolina.

II. CONTAMINANTS AND SOURCES

In the context of this study, a contaminant is defined as any substance found in a garden's soil or used in gardening practices that is potentially hazardous to human health. 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; Järup, 2003). Sources of these contaminants may include prior land uses, human activity in the surrounding area, and choices about what people bring into the garden (See Figure 2). This study also considers pesticides, which are defined as any substance used to kill or repel any animal or plant pests in a garden, including organic, natural, and synthetic products. Gardeners can be exposed to pesticides through residues in the soil from historical use or from a lack of

safety precautions when using these products. Proper label-reading and use of safety equipment can reduce hazards associated with direct pesticide use in the garden.

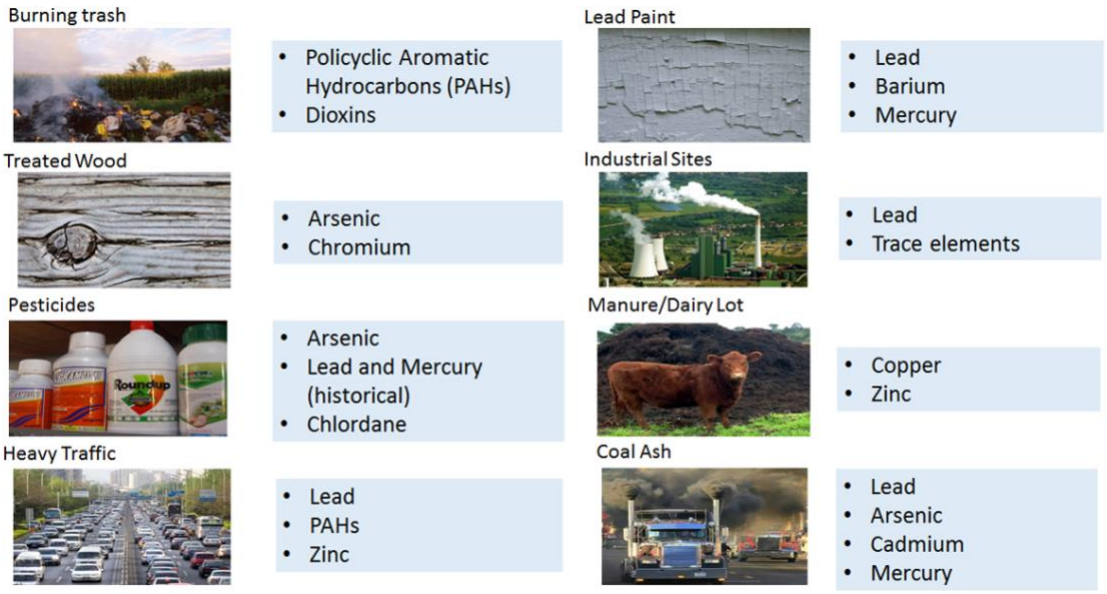

Figure 2: Primary potential sources of contamination to community gardens and associated contaminants

In visits to case study gardens and during conversations with garden managers, the research team specifically looked for the presence of a variety of common potential sources of contaminants. This list was based on a thorough review of previous research and relevant literature and included railroad ties, treated wood, evidence of non-biodegradable wood, found metal objects and art, rain collection systems, evidence of imported materials and soil amendments (especially biosolids), and pesticide containers. Railroad ties can be a source of PAHs if they have been treated with a protective layer of creosote, a coal-derived product. Treated wood and non-biodegradable wood, especially wood treated prior to 2003, often contains chromated copper arsenate, a weather-resistant substance that can leach and cause contamination. Found metal objects and art can contain heavy metals that leach into soils, and rain collection systems may be contaminated by chemicals in roofing materials if the source of the harvested rainwater is runoff from a rooftop. Imported materials such as compost from other sites or municipal leaf waste, or soil amendments like lime, are often unregulated and untested for contaminants, and may cause

issues. Finally, the team included notes on any visible pesticide containers because pesticides can be a source of contamination if they are improperly applied to a community garden.

During interviews, garden managers were asked about their management choices as well as land use history of the garden and surrounding areas, including: buildings built before 1978, coal-fired power plants, landfills, informal waste dumps, heavy traffic roads or parking lots, industrial or commercial sites, or old dry cleaners (Crozier et al., 2016).

Figure 3: DUSRC staff observe as Forsyth County Extension Agent Megan Gregory takes a soil sample.

Contaminants and Exposure Results

Research results on pesticide use in gardens were consistent across survey respondents and case study gardens. While gardeners commonly expressed that they were "highly motivated" by maintaining an organic and natural lifestyle, all six case study gardens regularly used some form of pesticides, both synthetic and organic, in their gardens. This trend persisted in the survey responses, with 56% of respondents reporting that their garden used pest control products and 31% that their garden used weed control products, with a moderately even distribution of "natural" or "organic," and inorganic or synthetic products in these figures. Synthetic pesticides such as Roundup® and organic pesticides such as neem oil, diatomaceous earth, and *Bacillus thuringiensis* were most commonly mentioned in interviews, focus groups, and survey responses.

The most significant historic land use of concern in all of our case study sites was proximity to at least one building built before 1978. This indicates that these gardens may be risk of of lead paint contamination from the current buildings or from buildings demolished on site that were likely built during the same era. Other historic land use concerns such as former or current dry cleaning facilities, industrial and commercial sites, and landfills were not found at the case study gardens, though due to our small sample size this does not rule out the significance of these potential sources at other gardens across the state.

In terms of current land use concerns, the most common potential source of contamination was roadways and runoff. All case study gardens were within two miles of major roadways and many were adjacent to parking lots (as represented by "Motor Vehicles" in Figure 4a). Interviewees and focus group participants across multiple gardens voiced concern about use of chemicals by neighboring properties or groundskeepers. This was matched by common concern from gardeners about contaminants from runoff.

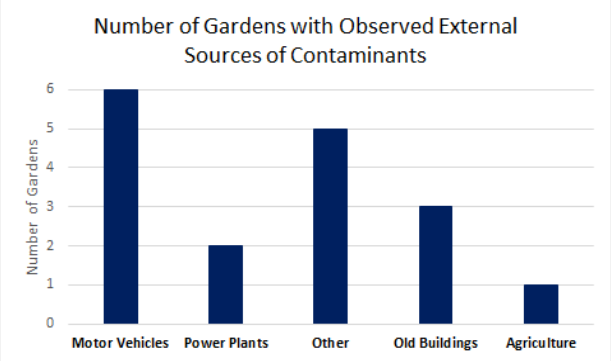

Figure 4a: Number of case study gardens near potential external contaminant sources.

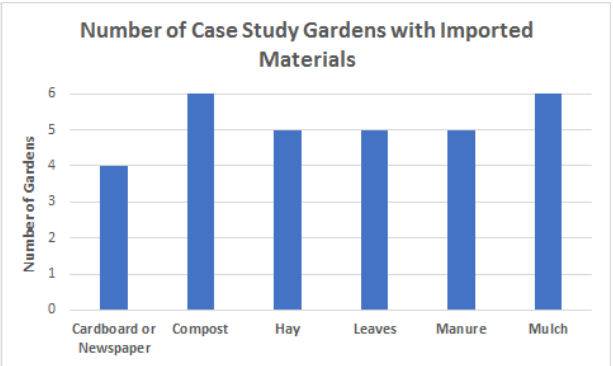

Figure 4b: Number of case study gardens that contained imported materials, by type of material.

We discovered that in the majority of cases, gardeners bring in materials (including soils) from outside the garden, rather than employing materials that are already present on the site. Management choices about which materials to use in the garden may therefore have more of an impact on the presence of contaminants and the potential for gardener exposure than initially anticipated at the outset of our study. At the six case study gardens, the imported materials most often discussed by managers and gardeners and observed during visits were mulch (158 mentions/observations), compost (71 mentions/observations), manure (41

mentions/observations), and leaves (30 mentions/observations). Choices about which materials to bring into the garden, and where to source those materials from, were most frequently based on cost. It does not appear that potential for contamination was a key factor in decision-making about imported materials. The prevalence of imported materials presents challenges to determining which contaminants are likely to be present as our analysis suggests that tracing the disjointed lifecycle and contaminant potential of these "imported" materials would be challenging for garden managers.

Currently there is little research available on the potential for contamination and human exposure for many of the materials we found most commonly in the case study gardens. Due to the large quantities of these imported materials we found in gardens, there is a potential for this to be a large and significant issue if the materials are in fact contaminated. If contamination of "imported" materials in gardens is an issue, it is a pervasive one. Therefore, this is a valuable topic for further research and study by the DUSRC and others interested in this topic.

III. EXPOSURE AND SAFETY

There are a number of pathways through which contaminants in community gardens can enter the human body and cause harm. The three main pathways of concern are ingestion, inhalation, and direct contact. Ingestion can occur when individuals eat produce that is covered in contaminated dirt or pesticides or produce that has taken up contaminants into its tissue (Defoe et al., 2014) or when people directly eat dirt, which is especially common among young children. Inhalation can occur during gardening by breathing in contaminated dust or when spraying or applying pesticides (Aktar et al., 2009). Finally, direct contact is mostly a concern with pesticides and other chemical products that get onto a person's skin while being handled or applied (Aktar et al., 2009).

A combination of garden management practices, individual gardening practices, and preparation of produce may increase or reduce the potential for exposure to contaminants (Kim et al., 2014). Individuals can protect themselves from exposure to contaminants in gardens by wearing gloves and other protective equipment, washing and peeling produce before eating it, watching children in the garden, and washing hands, clothing and tools regularly. Managers can reduce the presence of contaminants in the garden and in produce by capping contaminated soils (putting

down an impervious surface); using raised beds with imported, clean soils; planting crops away from roads and old buildings; and assigning rules regarding the use of pesticides and other products. Managers can also avoid use of materials that bring contaminants into the garden including railroad ties, found metal objects, or treated wood, especially wood treated before 2003, at which time the use of chromated copper arsenate was stopped (Heiger-Bernays et al., 2009; Weller Clarke et al., 2015; Crozier et al., 2016).

Exposure and Safety Results

Community gardeners' choices around hand washing, produce washing, and use of protective equipment were varied. A strong majority of survey respondents reported that they "Always" wash produce and hands (Figure 5). However, focus groups at our six study gardens added nuance to this finding. Though focus group participants often washed produce in their homes, many ate produce right off the plants in the garden. Focus group participants also described that only cursory rinsing of hands, shoes, and tools in the garden rather than full washing was common due to a lack of clean water sources and cleaning products in the garden or a lack of concern about the potential health impacts of dirt on produce.

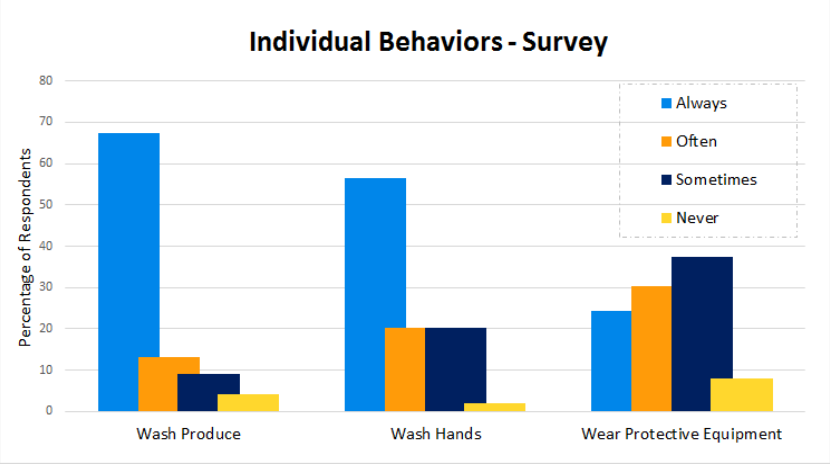

Figure 5: Survey respondents' self-assessed frequency of using individual exposure reducing behaviors

When discussing the use of protective equipment, survey respondents provided more diverse responses, with "Sometimes" being the most common answer by a small margin for how frequently survey respondents wear protective equipment (Figure 5). Again, the in-depth case studies provided some nuance to this finding. The majority of case study participants did not often use gloves, explaining that gloves are inconvenient or obtrusive and generally unhelpful.

Case study participants' use of protective equipment when applying pesticides was highly varied and often based on individual preference for more or less protection. One gardener specifically mentioned that the garden manager stresses the importance of reading labels when using garden products, but this concept did not come up during discussions at other gardens.

Results on management choices across the six case study gardens were more consistent. All case study gardens used raised beds in part or all of their area and brought in at least some soils from outside. None of the case study gardens used arsenic-treated wood or railroad ties in their garden. The case study gardens also did not contain found metal art or objects. As discussed above, pesticide use by managers was common, though managers regularly used integrated pest management. Here, integrated pest management is defined as using a combination of pest/weed control products and other manual or natural pest and weed control actions. In other words, an informed, limited, and selective use of products in parts of the garden only when there was a specific weed or pest that needed attention. For example, several of the gardens used herbicides products on pathways and other pesticides in other, non-productive areas of the garden site.

IV. AWARENESS AND BEHAVIOR

This study was grounded in public health and behavior change theories. Rosenstock's 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 that threat (Rosenstock et al., 1988). Thus, behavior change depends on more than just the availability of information. Another theoretical framework for this study is community-based social marketing. Part of this strategy is the use of psychological principles and identification of benefits and barriers to behavior change (MacKenzie-Mohr, 2000; MacKenzie-Mohr and Smith, 1999). In order to reduce exposure, according to the community-based social marketing framework, it is necessary to discover not only what individuals know and understand about the issue, as well as baseline behaviors and choices by gardeners and managers, but also what barriers and motivations affect key behaviors that will increase or decrease exposure potential.

Awareness and Behavior Results

To understand the barriers and motivations to promoting healthy gardening actions, we examined awareness, knowledge and concern on this topic. Case study participants seemed to be more knowledgeable about pesticides than they were when it came to other contaminants. Many were able to discuss different types of chemicals and pesticides and describe health effects and safety precautions associated with them. Participants were less likely to mention soil contaminants or exhibit awareness of their sources, health risks, or how to mitigate or reduce exposure, though a number of participants expressed awareness of the hazards associated with lead contamination in gardens (Figure 6). Survey respondents' self-assessed knowledge of the health impacts of contaminants showed 47% of respondents knowing a "moderate amount" about pesticides and 37% knowing a "moderate amount" about soil contaminants. Based on regression analysis, self-reported higher knowledge of contaminants was higher among participants who reported higher levels of education. Knowledge of pesticides was correlated with higher levels of reported concern about health impacts. While 76% of survey respondents said they were concerned about health impacts of consuming produce with pesticides on it, fewer (51%) were concerned about health impacts of soil contaminants.

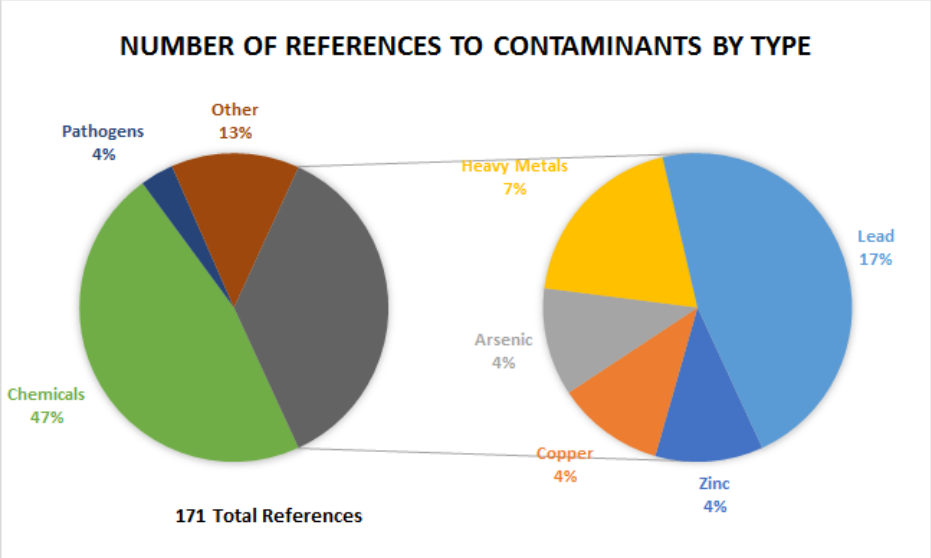

Figure 5: Number of times case study participants mentioned contaminants, chemicals, and pathogens by type in focus groups and interviews. The pie chart on the right shows a detailed view of the dark gray section (36% slice) on the chart to the left, which breaks down the frequency of mentions of specific common contaminants.

When discussing specific potential sources of soil contamination at their gardens, interviewees and focus group participants were able to name sources such as arsenic in treated wood, lead paint, road runoff, and neighbors' use of chemicals. This 'source oriented awareness' was

common where gardeners we spoke to were selectively well-educated on specific sources of contaminants. 'Contaminant oriented awareness' however, in which gardeners have knowledge about specific contaminants and the potential sources and health risks, was not observed in the case studies.

This study also identified barriers and motivations for making safe gardening choices that could reduce exposure to contaminants. One of the primary barriers to action was simple lack of awareness or concern for these issues (see Fig 7). Managers and gardeners who were interested in taking action encountered significant barriers to learning what contaminants were present, including the high cost and difficulty of interpreting tests for soil contaminants and a lack of access to land use history records and information on the sources and lifecycle of imported materials. At case study gardens, the most common barriers related to changing behaviors to decrease potential exposure to contaminants included a lack of economic and human resources, challenges accessing information, and a lack of urgent concern about contaminants. Finally, we found that the presence of active community engagement, including education and engagement of diverse communities, and concern for food security and health were significant motivators for gardeners as they made choices about how to manage and interact with their gardens in ways that could reduce exposure to contaminants.

Soil Testing

All managers and many participants at our six case study gardens were aware of the free soil testing service provided by the North Carolina Department of Agriculture and many of the managers had used this service. While this free soil nutrient testing service does include zinc and copper, it does not test for the other major soil contaminants of concern which require using different methods. Few case study participants had tested their soil for contaminants such as heavy metals, PAHs, or PCBs, and many were eager for information on where and how to get this testing done as they were not aware of the options for this type of testing. In the survey, 22% of garden managers said their garden has had its soil tested for contaminants, though some of the write in responses showed respondents were sometimes confused about the distinction between nutrient testing and contaminant testing, so this number may be inflated.

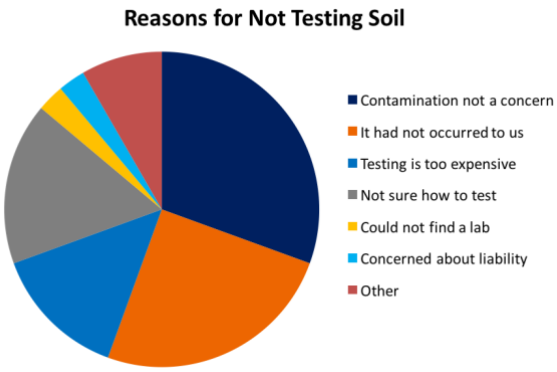

Figure 7: Survey respondents' reasons for not testing soil.

One garden manager who had done intensive soil contaminant testing expressed how difficult it was to interpret results, and the lack of resources on topics such as 'what is a safe and unsafe level of certain contaminants in garden soil.' This lack of information on how to interpret and apply soil contaminant testing results to make changes for safety in the garden was echoed in comments by other case study and survey participants (Figure 8).

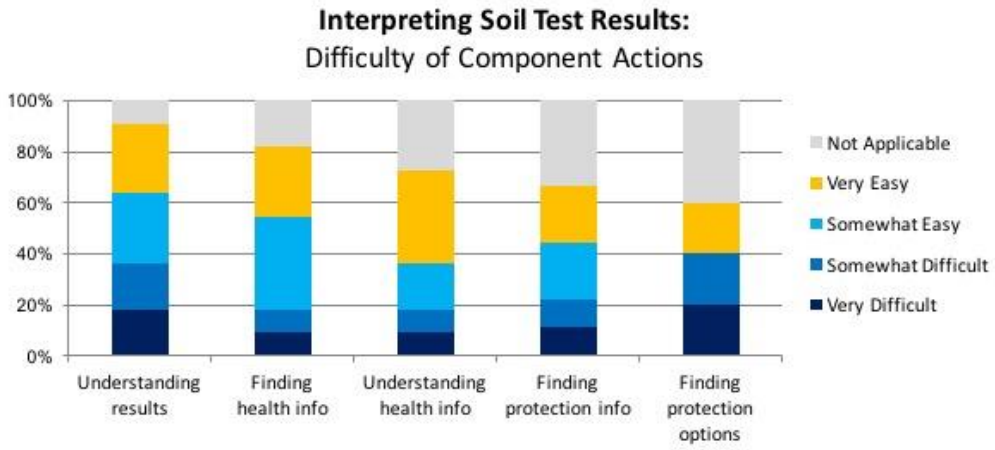

Figure 8: Ease of understanding soil test results as reported by survey respondents

V. COMMUNICATION

The final component of this research focused on understanding the most effective communication and outreach methods to communicate with community gardeners in North Carolina. Based on the previously discussed results, we are able to identify key aspects of community gardeners' awareness of contaminants and associated health risks, as well as their

motivations and barriers to changing their behavior to reduce exposure, in order to develop a communications strategy tailored to the target audience (MacKenzie-Mohr, 2000; MacKenzie-Mohr and Smith, 1999). However, beyond identifying motivations and barriers to behavior change, another key aspect of community based social marketing theory is to identify the places where audience members encounter messaging, whether this is a physical location or simply a type of media, in order to ensure a high level of attention and engagement (Lee and Kotler, 2014). Lee and Kotler (2014) recommend distributing messaging through existing communication channels, as well as locating messaging where members of the target audience "hang out." To discover the best way to educate and communicate about soil contamination to gardeners, this study collected information on the communications pathways and trusted information sources already in use by the target audience (gardeners and managers involved in North Carolina community gardens).

Communication Results

Survey respondents reported using the Internet (85% of respondents) and gardening-focused organizations (80% of respondents) as their main source of information on garden-related contaminants and pesticides. Case study participants expressed similar preferences about their sources of information. These participants expressed a preference for using academic or university-based sources of information and organizations that specifically supported community gardens, especially North Carolina State University and the North Carolina State Cooperative Extension. Case study participants mentioned a wide variety of information sources, from academic institutions to their own knowledge from previous education or life experiences (Figure 9a).

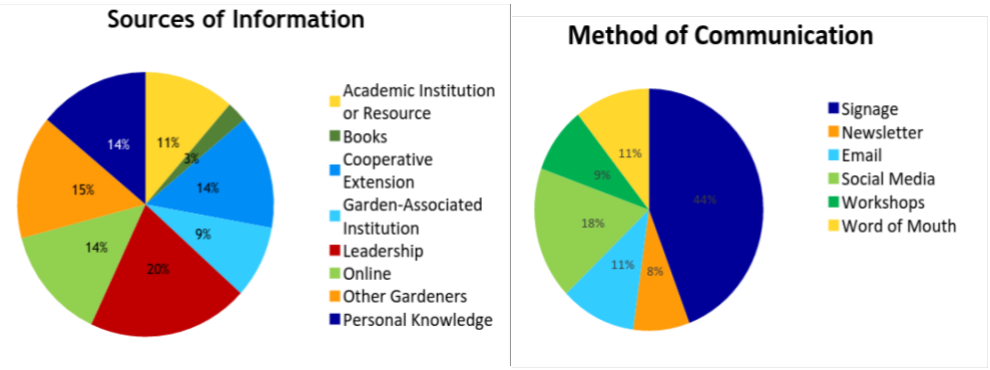

Figure 9a & 9b: Sources of information (a) & methods of communication (b) preferred by case study participants

Case study gardens also used a variety of methods to communicate information among garden participants (Figure 9b). In alignment with survey results, which indicated that the internet was widely used as a source of information, case study garden participants often used both social media and email to communicate information. At the same time, as suggested by Lee and Kotler (2014), putting information in the gardens where participants are working in the form of signage was a common practice, and it was preferred by gardeners and managers alike for communicating important information. While managers most frequently reported communicating with gardeners through signage in the garden, as well as through email communication, gardeners preferred to use "word of mouth" when communicating among themselves.

Our research also unearthed some significant barriers to communication and education in community gardens. First and foremost, while there is interest and enthusiasm for communicating and educating on the topic of soil contaminants and pesticides, managers are often severely limited by constraints of time as well as financial, human and physical resources. Several managers described that while they have strong communication channels with their gardeners, they do not have the time to use those channels for education. One manager mentioned that the garden was working to hire for a new position focused entirely on communication, education, and coordination of gardens in their area.

Another common barrier to effective communication was language and translation. Many of the gardens listed in the North Carolina Community Garden Partners database cater to diverse populations and community members that speak many languages. Two of the case study gardens we visited for this project had gardeners who spoke little or no English. One garden worked closely with ESL services and translators, but even this manager lamented that the garden did not have the capacity to provide materials or education in multiple languages.

VI. RECOMMENDATIONS

Reducing the Potential for Exposure

We found that there are simple actions that community gardeners or garden managers can take to reduce the potential for exposure to soil contaminants and pesticides. The first step is to understand what contaminants may already be in the garden or on a property being considered for a garden. Taking some time to identify potential contaminant sources (e.g. buildings

constructed before 1978 or dry cleaners as discussed above) can help gardeners understand what contaminants may present and related health concerns that can inform their decision making about whether to test for soil contaminants and, if so, which ones. We have listed a number of helpful resources below to help gardeners learn about these sources and associated contaminants and to find low cost options for soil testing.

Finally, whether or not gardeners have a detailed understanding of the contaminants in the soil at their site, there are a number of low cost, easy ways to reduce exposure by making some fairly simple behavioral and management choices. Gardeners can reduce exposure to contaminants by wearing gloves and protective equipment when working with contaminated soil or pesticides, wash produce and peel root crops before eating them, monitor children in the garden, and plant crops that are less susceptible to contaminant uptake. Managers can reduce contaminant potential by locating gardens away from contaminant sources such as old buildings or former industrial sites, installing raised beds, capping soils, providing protective equipment for gardeners, increasing organic matter in the soil, and monitoring pH. Educating garden participants and communicating best practices for contaminant reduction and exposure reduction is another key activity to prevent or reduce exposures.

Figure 10: Graduate student Tess Leuthner and undergraduate Lindsay Holsen on a site visit, June 2017.

Educating Gardeners About Contaminants and Pesticides

Garden support organizations, such as nonprofits or educational institutions, as well as garden managers and other players, are well-positioned to educate and spread awareness on this topic. Our research shows that while there is generally high awareness of pesticides, their health risks, and the proper safety precautions, there is low awareness about soil contamination as well as the methods for preventing or reducing exposure. Where there is awareness of soil contaminants, it is specific to one material or source, and is not comprehensive. Education on the topic of soil contaminants and pesticides should therefore focus on providing a comprehensive understanding of all potential contaminants, their common routes to exposure and associated health risks. Our research found certain similarities between all the gardens we visited: old buildings, roadways and runoff, large amounts of imported materials with uncertain origins and contaminant loads, lack of protective equipment, and varied levels of adherence to the practice of washing produce, hands, and clothes.

Education can focus on these topics, but must also be flexible and customizable to each garden's unique circumstances, since contaminant potential and risk varies as widely among the diverse types of gardens of North Carolina. Keeping in mind public health and behavior change theories, education should provide not only awareness, but also actionable choices gardeners and managers can use to keep their gardens safe and healthy. Our research also shows that there appears to be a link between the participants' level of knowledge and their concern about health impacts to participants and their families; given this association, using health-oriented messaging may be effective in this education effort.

Our research demonstrates that garden support organizations, including extension offices and academic institutions, are trusted sources of information for gardeners, and therefore these outlets offer important opportunities to provide education and resources on this topic. Given that our results indicated that garden managers are limited by time, human resources, and money, providing educational opportunities in the form of pre-made, ready to distribute, and versatile materials is critical. Our research also shows the best avenues through which to communicate and educate on these topics include the Internet, word-of-mouth, and signage. We therefore recommend that materials used for community-based social marketing efforts should include garden signage, with graphic-heavy aids for gardens where participants speak other languages,

have low literacy levels, and/or for children. Materials for social marketing should also include pre-designed or web-based trainings for managers or participants to carry out at garden workdays or that individuals can view online on their own time, along with other educational materials that can be accessed online.

Increasing Garden Capacity

In addition to providing pre-made educational materials, there are a few ways that support organizations can help community gardens overcome contaminant issues by reducing barriers to behavior change and improving organizational capacity at gardens. Given that we found garden managers' lack of time to be a significant barrier to disseminating information about these issues to gardeners, support organizations could offer to provide trainings on these issues, either directly or through a "training of trainers" model such as the Master Gardener program offered through the North Carolina Cooperative Extension. Managers might also benefit from guidance on how to access and understand pertinent land use history records, including what "red flags" or potential sources to look for when they conduct research into the garden's prior/historical land uses or imported materials, as well as guidance on how to interpret soil testing results. Finally, providing access or connection to translation and language resources would significantly improve communication and education about reducing exposure to soil contaminants at North Carolina's many gardens with non English speakers, while allowing garden managers to pursue stated goals of increased diversity and inclusion in their community gardens.

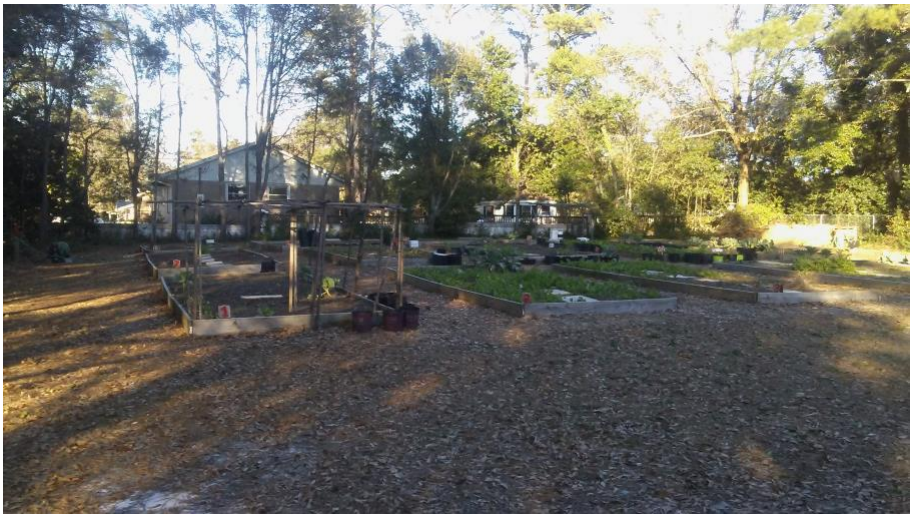

Figure 11: A community garden plot in eastern North Carolina.

VII. CONCLUSIONS

Community gardens are increasingly prevalent in North Carolina and across the United States. While serving as an important source of food security, educational opportunities, access to green space and outdoor recreation and community building, these sites also pose potential health risks to participants if soil contaminants are present. Our research demonstrated that while there is little current awareness of these risks among gardeners and garden managers, there are a number of fairly easy, low cost actions that can be implemented in order to determine if contaminants are present and to reduce exposures if they are detected. This document has provided a broad summary of our study and of its implications for actions community gardeners can take. A detailed description of this research, and of educational and outreach materials that we have developed based on our results, can be found at http://sites.nicholas.duke.edu/superfund/gardens/.

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early life exposures, later life consequences

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Contact us at SuperfundCEC@duke.edu

NC State Extension: https://www.ces.ncsu.edu/

Soil testing resources: **https://foodsafety.ces.ncsu.edu/foodsafety-soil-testing/**