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Behaviors to Reduce Heavy Metal Soil Contaminant Exposures among Community Gardeners

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Doctor of Philosophy

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Abstract

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By Candis Mayweather Hunter

Community gardens provide many benefits that should be balanced with possible risks of exposure to heavy metal soil contaminants in urban environments. Previous research has demonstrated that these risks may stem from the gardens' proximity to heavily trafficked roadways, buildings with lead-based paint, and other environmental hazards. Behaviors can be implemented to reduce potential exposures; however, some gardeners may be unaware of risks related to contaminated soils and methods to mitigate exposure. Using an exploratory mixed-methods approach grounded in the Theory of Planned Behavior, (TPB) this study investigated factors that influence community gardeners to conduct behaviors to reduce their exposures to heavy metal soil contaminants.

The qualitative phase of this research utilized five focus groups to explore the behavioral, normative, and control beliefs related to soil testing, composting, mulching, and handwashing among Atlanta community garden leaders. Findings suggest that gardeners have varied risk perceptions of soil contaminants. Additionally, study results indicated that gardeners value heavy metal soil testing as a method to improve the soil quality and grow healthy food; however, perceived liability was a primary hindrance to testing. A key finding was that study participants did not associate composting and mulching as practices to reduce exposure to soil contaminants. Challenges regarding hand hygiene included concerns about decreased exposure to salubrious bacteria, inadequate access to potable water, and limited availability of gloves and wipes.

Using questionnaire data from 500 community gardeners across the United States, the second phase of the research applied logistic regression to examine factors that influence intention to soil test and hand wash after gardening. Results reveal that attitudes, subjective norms, perceived behavioral control, lower education and garden methods without pesticides were statistically significant predictors of soil testing and handwashing intention. Both qualitative and quantitative data reveal the following TPB themes: 1) In general, gardeners experience positive attitudes toward soil testing and handwashing; 2) Gardeners, government agencies, and nonprofit organizations are perceived to influence these behaviors; and 3) Gardeners experience lower perceived behavioral control for soil testing. Study findings have implications for interventions related to soil testing policy, exposure science research, and environmental justice initiatives.

Investigating Community Gardeners' Behaviors to Minimize Soil Contamination Exposure:
A Mixed Methods Study

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Chapter 1: Introductory Literature Review

Community Gardens in the United States

Urban agriculture has been defined as *"*the growing, processing, and distribution of food and other products through intensive plant cultivation and animal husbandry in and around cities*"*(Bailkey & Nasr, 1999; Krishnan, Nandwani, Smith, & Kankarta, 2016; Mougeot, 2000). Although distinctions between urban agriculture and urban community gardens vary in the literature, community gardens are the most common type of urban agriculture (Santo, 2016). Community gardens have been defined as "spaces which are managed and operated by local community members in which food or flowers are cultivated'(Guitart, Pickering, & Byrne, 2012; Pudup, 2008). Community gardens differ from private and home gardens in that community gardens typically involve community guardianship, access, and degree of self-governance (Ferris, Norman, & Sempik, 2001).Community gardens can be defined in multiple contexts including neighborhood, school, workplace, faith communities, hospitals, senior homes and prisons (Draper & Freedman, 2010).

In the United States, community gardens have experienced periods of immense growth and decline depending on federal policies, socioeconomic climate, and environmental/food justice movements. Periods of urban community garden growth have been attributed to vacant lot cultivation centers in the 1890s, subsistence gardens during the Great Depression in 1930's, World War II Victory Gardens Campaigns in the 1940s, and to the resurgence of vacant lot gardening in the beginning in 1970s to the present (Drake & Lawson, 2014; Draper & Freedman, 2010; Lawson, 2005) Moreover, community gardens support interests that are emergent in the local food movement to obtain food from nearby areas, to increase knowledge of food sources, and to promote sustainable growing practices (Allen, 1999).

The social, educational, environmental, health, and economic successes of community gardens have been well-documented in literature of multiple disciplines. Community gardens have been associated with public health benefits such as improved food security, nutrition access, mental health, and physical activity (K. Alaimo, Packnett, Miles, & Kruger, 2008; K. H. Brown & Jameton, 2000; Litt, Schmiege, Hale, Buchenau, & Sancar, 2015). Social and educational benefits of community gardens are sharing of intergenerational knowledge and skills, cultural heritage, increased social capital, and civic engagement (Katherine Alaimo, Reischl, & Allen, 2010; M. M. White, 2011). Environmental benefits include increased wildlife habitat, biodiversity, pollination, and climate change mitigation (K. H. Brown & Jameton, 2000; Santo, 2016). Documented economic advantages to community gardens and urban agriculture are job creation, increased land values, and redevelopment opportunities (McClintock, Mahmoudi, Simpson, & Santos, 2016; Voicu & Been, 2008). Despite these benefits, urban community gardeners must also weigh the potential risks of sources of contaminants in urban soils.

Sources of Soil Contaminants in Urban Gardens

Urban garden soils may contain multiple potential hazards from sources such as industry, pesticide and chemical fertilizer applications, animal feces, drug paraphernalia, and garbage (Ajmone-Marsan & Biasioli, 2010; Li, Sun, Ren, Luo, & Zhu, 2018). Additionally, contaminated irrigation sources, fill dirt, and compost applied to urban garden soils may present chemical and microbial risks (B. F. Kim et al., 2014). Due to current and former anthropogenic activities, urban soils may have high concentrations of chemical contaminants such synthetic organic compounds, polycyclic aromatic hydrocarbons (PAHs), and heavy metals/metalloids. Synthetic organic contaminants in soil such as polychlorinated biphenyls, dioxins, and may come from waste incineration, combustion, landfill leachate and metal production (J. Alloway, 2004; Brevik & Burgess, 2012). Sources of PAHs in urban soil include petroleum, coal, wood and automobile combustion, re-suspension of road dusts and deterioration of asphalt and tires (Marquez-Bravo et al., 2016). Heavy metals have been extensively studied due to their widespread existence, accumulation, and non-biodegradability in soils (Jan et al., 2015). Heavy metals such as lead and cadmium and metalloids such as arsenic are some of the most common contaminants in city soils. Based on their potential for human exposure and prevalence, these chemicals are ranked among the top 10 priority hazardous substances by the Agency for Toxic Substances and Disease Registry and are listed as top chemical hazards that threaten food safety by the World Health Organization.

Lead is the most frequently studied heavy metal in urban soils and has been cited as the one of the most pervasive soil contaminants in the world (Steffan, Brevik, Burgess, & Cerdà, 2018). Sources of lead in soil include lead-based paint and gasoline, vehicle emissions, waste incinerators, smelter sites, road dusts, and other industrial activities. Lead may accumulate in soil over long periods of time, and factors such as soil conditions and weather can affect lead exposure and bioavailability (Chammi P Attanayake et al., 2014; Attanayake, Hettiarachchi, Martin, & Pierzynski, 2015b; J. J. Clark & Knudsen, 2013). Lead exposure has been associated with several adverse health outcomes in children including behavioral and learning problems, decreased IQ scores, and premature birth (Agency for Toxic Substances and Disease Registry, 2007). A systematic literature review of home and environmental lead interventions indicates that dust control and educational interventions are not effective in reducing children's blood lead levels. The article suggests that more studies may be needed to understand the role of soil contamination removal efforts in lowering blood lead levels among children (Yeoh et al., 2014). Many legacy sources such as historic gasoline deposits contribute to lead in soils, therefore household interventions could be unsuccessful if they aren't targeting outside soil lead sources. Moreover, several studies have shown that soil lead is strongly associated with children's blood lead levels (Filippelli & Laidlaw, 2010; M. A. Laidlaw, Mielke, Filippelli, Johnson, & Gonzales, 2005; Zahran, Laidlaw, McElmurry, Filippelli, & Taylor, 2013; Zahran, Mielke, et al., 2013).

Arsenic is a metalloid that occurs naturally in soils and groundwater in certain areas of the United States. Anthropogenic sources of arsenic in soil include lead arsenical pesticides, atmospheric deposition from air pollution sources, pressure-treated wood, mining, and smelting activities (Bissen &

Frimmel, 2003) In raised-bed gardens, arsenic has been shown to leach from chromated copper arsenate (CCA)-treated lumber structures into garden soils (Clarke, Jenerette, & Bain, 2015; Heiger-Bernays et al., 2009). Although the US Environmental Protection Agency banned use of CCA for residential and playground structure applications in 2003, a legacy of CCA potential exposure may persist through previously treated structures and waste. Chronic exposure to inorganic arsenic has been associated with dermal lesions, hypertension, diabetes, neurological effects, and several types of cancers (e.g., lung, skin, bladder) (Agency for Toxic Substances and Disease Registry, 2000; Yoshida, Yamauchi, & Fan Sun, 2004).

Potential sources of cadmium in soil include phosphate fertilizers, nickel-cadmium batteries, manufacturing scraps, mining and smelting operations, municipal sewage sludge, waste incineration, and landfills (Cullen, 2013). Among non-smoking populations, ingestion of cadmium-contaminated food is the primary exposure route. Due to cadmium’s high soil-to-plant mobility, several studies have shown that cadmium can bioconcentrate in plants and biomagnify up the food chain (Al Mamun et al., 2016; Shahid, Dumat, Khalid, Niazi, & Antunes, 2016b). Cadmium can translocate from soil to plants used as animal feed and food products such as wheat grains, rice, legumes, mushroom and some leafy vegetables (Shahid, Dumat, Khalid, Niazi, & Antunes, 2016a). Exposure to high levels of cadmium may affect kidney, bone, and lung functions (Agency for Toxic Substances and Disease Registry, 2009). To minimize potential risks associated with cadmium contamination in food, the World Health Organization has set maximum allowable values of cadmium for edible plants (Järup & Åkesson, 2009).

In summary, important factors that can affect heavy metal and metalloid contamination in urban soils include proximity to heavily trafficked roadways, industrial facilities, and older (pre-1978) housing and buildings (Mitchell et al., 2014b). Additionally, past and current site activities including construction, mining, manufacturing, landfill waste, pesticide application, waste burial, lead paint disposal, and agricultural runoff are contributors to contamination in urban soils (Ajmone-Marsan &

Biasioli, 2010; B. J. Alloway, 2012). To protect people from exposure to toxic chemicals in soils from these sources, the US Environmental Protection Agency has developed Soil Screening Levels (SSLs) that are primary used for Superfund site cleanup (Table 1.1). If a site has contaminant levels above the SSLs, it triggers further investigation through a Phase 1 (site inspection and historical record review) and Phase 2 (soil sampling and laboratory tests to confirm the presence of toxins). A challenge is that these SSLs are not specific for garden soils and do not take bioavailability into account; therefore, each state has authority to establish appropriate screening levels based on the background concentrations of contaminants at each site.

Table 1.1: Soil Screening Levels (SSL), Sources, and Health Effects for Lead, Arsenic and Cadmium

Chemical	Environmental Protection Agency (EPA) Residential Use, Exposure Soil SSL (ppm)	University of Georgia (UGA) Extension Service Advisory Guide Lines (ppm)	Sources	Health Effects
Lead* (Pb)	<100 (low risk) 100-400 (potential risk) >1200 (high risk)	<75 (low risk) 75-400 (potential risk) >400 (high risk)	Lead-based paint and gasoline, vehicle emissions, waste incinerators, smelter sites, road dusts, tire weights, burning coal, lead-acid batteries, solder	Neurological impacts, encephalopathy, bone deterioration, hypertension
Cadmium (Cd)	2	<2 (low risk) 2-39 (potential risk) >39 (high risk)	Phosphate fertilizers, nickel-cadmium batteries, manufacturing scraps, mining and smelting operations, municipal sewage sludge, waste incineration, and landfills, burning coal, galvanized water pipes	Liver and kidney damage, cancer, decreased bone density, hypertension, diabetes
Arsenic (As)	0.4	<20 (low risk) 20-41 (potential risk) >41 (high risk)	Lead arsenate pesticides, atmospheric deposition from air pollution sources, pressure treated lumber, mining and smelting activities, burning coal	Gastrointestinal damage, skin damage, cancer, neurologic impacts, heart and liver damage

Table adapted from Brevik, E.C. and L.C. Burgess, *Soils and human health*. 2012: CRC Press., Kim, B.F., et al., *Urban community gardeners' knowledge and perceptions of soil contaminant risks.* PLoS ONE, 2014. **9**(2), and University of Georgia-Urban Gardening: Assessing Soils for Contamination https://secure.caes.uga.edu/extension/publications/files/pdf/C%201075_2.PDF

*Based on EPA Technical Review Workgroup Recommendations Regarding Gardening and Reducing Exposure to Lead-Contaminated Soils- Dec 2013 and Environmental Protection Agency (2012) Regional Screening Level (RSL) Resident Soil Table, available at www.epa.gov/region9/superfund/prg/

Soil Exposure and Bioavailability

Gardeners may be exposed to contaminated soils through dermal contact, ingestion and inhalation of soil particles and dust through gardening activities, tracking contaminated dust and soil in the home, and consuming produce that has not been thoroughly washed (Kessler, 2013). Soil ingestion is considered the primary direct exposure route for heavy metal contaminants such as lead (Henry et al., 2015; Hettiarachchi & Pierzynski, 2004). Although there are multiple pathways of soil contamination exposure, the bioavailability of the contaminant plays a major role in the risk of toxicity. Bioavailability has been defined as the percentage of a contaminant in soil that is available for absorption across biological membranes into organisms(Drexler et al., 2003; Hettiarachchi & Pierzynski, 2004).Only a fraction of the total concentration of a contaminant measured in soil is bioavailable. The remainder of the soil contaminant is unable to be adsorbed into organisms due to its attachment to soil components through various chemical mechanisms. Standard soil tests determine the concentration of a chemical in a soil, but more extensive bioassay tests must be conducted to determine bioavailability (Bruce, Noller, Matanitobua, & Ng, 2007; Li et al., 2018; Misenheimer et al., 2018).

The concentration of a chemical in soil that is bioavailable to plants depends on soil properties such as soil pH, solubility, oxidation-reduction (redox) potential, mineralogy, soil texture, concentration of other contaminants, and organic matter (Khan, Khan, Khan, Qamar, & Waqas, 2015; Wilson, Tighe, Paterson, & Ashley, 2014). Some studies have shown that the addition of organic matter and compost, as well as the adjustment to soil chemistry and pH may reduce the bioavailability of some heavy metals in soils (Golia, Dimirkou, & Mitsios, 2008; Madejon, Madejon, Burgos, Perez de Mora, & Cabrera, 2009; Park et al., 2011). For example, addition of phosphorus and biosolids with high iron and manganese can decrease the bioavailability of soil lead (Attanayake et al., 2015b; S. Brown, Chaney, Hallfrisch, & Xue, 2003).

There are diverse opinions in the literature regarding heavy metal bioaccumulation and safety of community garden produce. Several studies have shown that heavy metal accumulation in urban garden produce is relatively low, and should not present a hazard to human health (S. L. Brown, Chaney, & Hettiarachchi, 2016; Defoe, Hettiarachchi, Benedict, & Martin, 2014; M. B. McBride, H. A. Shayler, J. M. Russell-Anelli, H. M. Spliethoff, & L. G. Marquez-Bravo, 2015; M. B. McBride et al., 2014). Therefore, many guidelines have emphasized minimizing direct soil exposure instead of indirect exposure through produce. However, other studies have shown that some crops exhibit heavy metal concentrations that exceed health regulatory standards (Liu et al., 2013; Säumel et al., 2012) and emphasize a more precautionary approach towards consuming produce that can bioaccumulate heavy metals. For example, cadmium has been shown to translocate from soil to plants, particularly in wheat grains, rice, legumes, mushroom and some leafy vegetables (Shahid et al., 2016a). Rice root cells and certain fern species can accumulate arsenic (Zhao, Ma, Meharg, & McGrath, 2009). Carrots and some leafy vegetables have been shown to have lead levels above World Health Organization and European Union maximum allowable limits (Chammi P Attanayake et al., 2014; M. McBride, 2013; Murray B McBride, Hannah A Shayler, Jonathan M Russell-Anelli, Henry M Spliethoff, & Lydia G Marquez-Bravo, 2015).

Best Management Practices to Minimize Exposure to Soil Contaminants

Soil testing, installing raised beds, mulching to cover bare soil, amending soil with phosphorus and compost, sustaining near neutral soil pH, and locating gardens away from heavily trafficked roadways and other pollutant sources are soil management practices related to mitigation of contaminants (Katherine Alaimo, Alyssa W. Beavers, Caroline Crawford, Elizabeth Hodges Snyder, & Jill S. Litt, 2016a; S. L. Brown et al., 2016; Kessler, 2013; Mitchell et al., 2014b; Scheckel et al., 2013;

U.S. Environmental Protection Agency, 2011). Each of these best management practices has both benefits and challenges. Contaminant soil testing provides the concentration of soil toxicants; however, characterization of the garden plot depends upon where the soil samples are collected due to spatial variability of contaminants. Therefore, representative soil sampling should be conducted according to recommended guidelines (U.S. Environmental Protection Agency, 2011). Installation of raised beds should ensure that materials used to construct the frame as well as the fill dirt, compost, and mulch are uncontaminated. Copper-arsenate treated lumber and railroad ties can potentially leach materials into the soil of raised beds. A fabric or other type of barrier should be placed underneath raised beds to limit plant roots extending to potentially contaminated soil underneath. Mulching areas around raised beds and other soil plots can limit exposure from windblown soil and dust contaminants. The sources of mulch should be examined prior to garden application to prevent introduction of harmful chemicals and pests. Chemicals in phosphorus fertilizer and compost may bind to heavy metals in soil to decrease heavy metal soil mobility (C. P. Attanayake et al., 2014; Attanayake et al., 2015b). An appropriate balance of soil nutrients and organic matter may facilitate dilution of some heavy metals in soils (Chammi P Attanayake et al., 2014; Ekvall & Greger, 2003); however, compost should be matured and at the appropriate temperature to kill pathogens prior to garden application (Wichuk & McCartney, 2010). Hygiene habits such as wearing gloves, leaving gardening shoes and gear outside, peeling root vegetables, washing hands, fruits, and vegetables and are recommended actions to limit soil contact.

Study Conceptual Framework: Theory of Planned Behavior

The Theory of Planned Behavior (Figure 2.1), an extension of the Theory of Reasoned Action, is one of the most frequently used theoretical conceptual frameworks to investigate influencing factors of behaviors(Armitage & Conner, 2001; McEachan, Conner, Taylor, & Lawton, 2011). The premise of the Theory of Planned Behavior is that behavioral intention is a primary predictor of behavior. Behavioral intention is the perceived likelihood or readiness to perform the behavior. The theory suggests that behavioral intention is strongly and positively correlated with the performance of the behavior(I Ajzen, 1991). Numerous studies that have applied the Theory of Planned Behavior have indicated that behavioral intentions are good predictors of behavior, particularly when the behavior is under volitional control, a behavior that a person can willfully decide whether to implement or not to implement(Icek Ajzen & Fishbein, 2005). The three primary predictors of behavioral intention include: Attitude toward the Behavior, Subjective Norms, and Perceived Behavioral Control. The theory hypothesizes that stronger perceived behavioral control and higher favorability of attitudes and subjective norms toward a particular behavior, the stronger the behavioral intention(I Ajzen, 2002; Montano & Kasprzyk, 2015).

Attitude toward the behavior is the extent to which the behavior is favorably or unfavorably valued. Subjective norms are perceived pressures to perform or not perform a behavior based upon the influence and value of opinions among influential individuals and groups, also called referents. Perceived behavioral control is influenced by the presence of variables that make a behavior easy or difficult to perform. Perceived behavioral control is analogous to the combination of self-efficacy, the belief that one has the necessary skills perform the behavior(Bandura, 1977), and perceived control, whether an individual views a behavior is under their influence. Perceived behavioral control is an antecedent to intention of the behavior and can also directly influence behavior if volitional control is high. The actual control of the behavior can moderate the effect of perceived behavioral control. Actual behavioral control can involve multiple internal (e.g. skills, intelligence) and external (e.g., legal barriers, political climate) control factors, and these internal and external factors are typically explored during the Theory of Planned Behavior formative research stage. Due to the lack of standard methods to adequately assess actual behavioral control, most studies utilize perceived behavioral control as a proxy for actual behavioral control(Fishbein & Ajzen, 2015). The theory posits that attitude toward the behavior, subjective norms, and perceived behavioral control are all influenced by behavioral, normative, and control beliefs.

Behavioral beliefs are underlying convictions that the behavior will produce a given outcome, and behavioral beliefs serve as an antecedent of the attitude of the behavior. Normative Beliefs are perceived behavioral expectations of referents. Normative beliefs weighted by the motivation to comply determine the subjective norm. Control beliefs are beliefs about the presence of factors that may serve as barriers or facilitators to performing the behavior. Control beliefs can be influenced by perceived power and serve as an antecedent of perceived behavioral control. Recent updates to the Theory of Planned Behavior propose that a range of background factors such as individual, social, and knowledge factors can influence behavioral, normative, and control/self-efficacy beliefs (Fishbein & Ajzen, 2015).

The Theory of Planned Behavior has demonstrated empirical strength in prediction of individuals' intentions for health-related behavior in numerous studies (Armitage & Conner, 2001; F. G. Kaiser & Gutscher, 2003; McEachan et al., 2011). Additionally, the theory has clear guidelines for construct measurement and analysis (Francis et al., 2004; Vincent, Riley, & Wilkie, 2015) and can provide insight into specific constructs for intervention development and evaluation (Sutton, 2010). The Theory of Planned Behavior has been applied to many environmental health behaviors such as food safety, lead poisoning prevention, recycling, water conservation, public transportation, green hotels, and other environmental related behaviors at work, home, and other settings (Bland, Kegler, Escoffery, & Malcoe, 2005; Blok, Wesselink, Studynka, & Kemp, 2015; Chao, 2012; Han, Hsu, & Sheu, 2010; Nye & Hargreaves, 2010; Oreg & Katz-Gerro, 2006; Pilling, Brannon, Shanklin, Howells, & Roberts, 2008). For example, a study examined Theory of Planned Behavior constructs for three food safety behaviors among foodservice employees including using a thermometer, hand washing, and sanitizing surfaces (Pilling et al., 2008). To examine influences on four lead poisoning prevention behaviors, Bland et al analyzed interview data of 380 child caregivers in Oklahoma utilizing some Theory of Planned Behavior constructs (Bland et al., 2005).

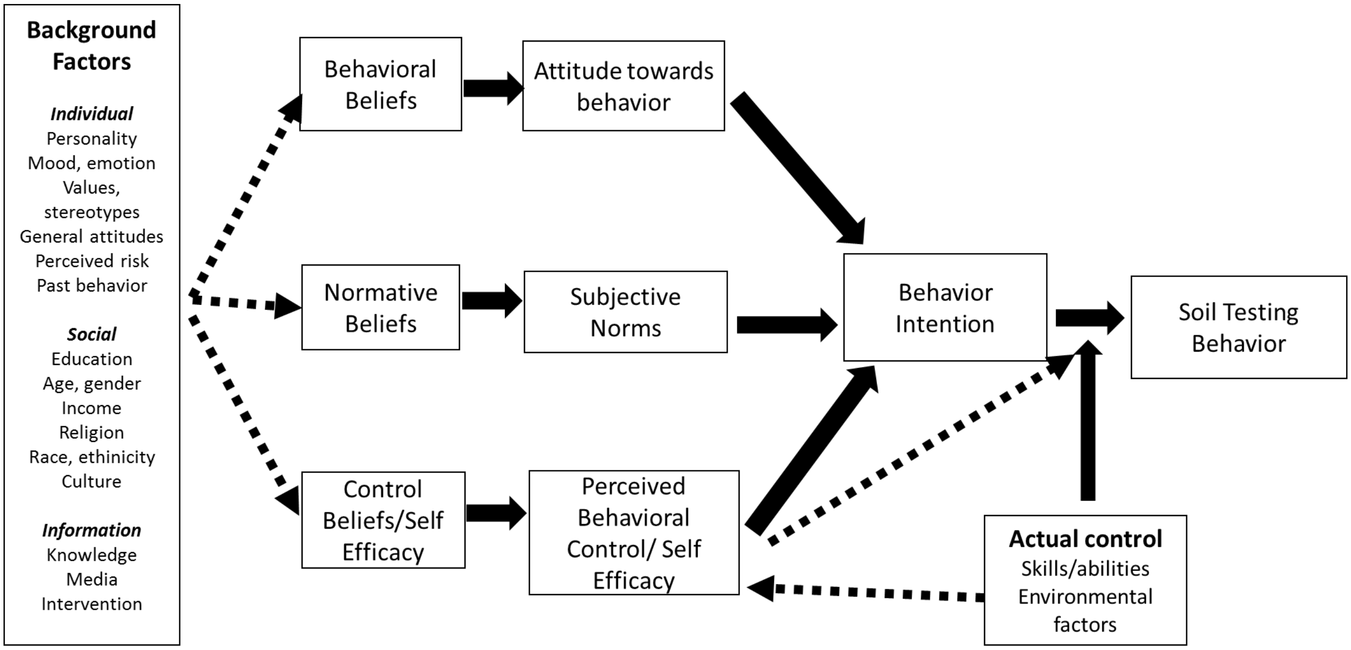

Figure 1.1: Theory of Planned Behavior

Adapted from Fishbein, M. and I. Ajzen, Predicting and changing behavior: The reasoned action approach. 2015, New York, NY: Routledge.

To effectively apply the Theory of Planned Behavior for a questionnaire, the following steps are required: (1) define the behavior and specify the research population, (2) formulate items for direct measures, (3) elicit salient beliefs shared by target population for indirect measures, (4) formulate items for indirect measures, and (5) prepare and test the questionnaire. Formative research and elicitation pilot work are required to identify salient behavioral, normative, and control beliefs(Fishbein & Ajzen, 2015; Francis et al., 2004). The pilot study should have a sample size of 25 to 30 participants that represent the study population (I Ajzen, 2018). Typically, formative research may involve in-depth interviews, however focus groups have also been used to for belief elicitation (K. M. Kim & Oh, 2015; York, Brannon, Roberts, Shanklin, & Howells, 2009). During the focus groups participants can be asked to list and discuss beliefs around outcomes, referents, and control factors related to a specific behavior. Focus groups may be particularly appropriate to understand modal salient beliefs which are the most commonly held beliefs among the target population.

Risk Perception

An important background factor to highlight within this Theory of Planned Behavior conceptual framework is perceived risk. To make informed choices regarding exposure to soil contaminants, one must have enough information to determine whether the perceived severity and possibility of experiencing personal harm from soil contaminants are sufficient for direct action. Definitions of risk vary depending on the context and discipline. Among public health disciplines, the meaning of risk reflects core paradigms of the respective fields. In environmental health, risk is often characterized as a function of hazard or toxicity and environmental exposure. From an epidemiological standpoint, risk is the probability that an event will occur within a given population. In behavioral sciences, risk has been conceptualized in multiple theories for the creation, implementation and evaluation of health interventions (Griffin, Dunwoody, & Neuwirth, 1999; Janz & Becker, 1984; Weinstein, 1988). In addressing complex environmental health issues that encompass multiple fields and stakeholders, risk has often been characterized as the summation of hazards and public outrage (Sandman, 1987). In addition to logic and facts, people's perceptions related to outrage and hazards are processed through mental strategies, often called heuristics (Paul Slovic & Peters, 2006). For effective communication about environmental health risks, the internal and external factors of risk perception should be evaluated (Morrone, 2011).

Risk perception involves the intuitive judgment of the likelihood and the implications of experiencing personal harm (P. Slovic, 1987; Weinstein, 1999). Risk perception is affected by complex cultural, psychological, sociological and environmental factors (Bickerstaff, 2004). Perceptions of environmental risks have been shown to be influenced by location, gender, race/ethnicity, socioeconomic status, proximity to hazardous waste and other factors (Marcon et al., 2015; Morrone, 2011). Risk perception and self-efficacy are important factors in engaging environmental health behavior change such as home radon testing and lead water testing (Duckworth, Frank-Stromborg, Oleckno, Duffy, & Burns, 2002; Oneal, Odom-Maryon, Postma, Hill, & Butterfield, 2013).

Critiques of the Theory of Planned Behavior

Due to its individual cognitive behavioral focus, the TPB has been criticized for its lack of accountability for the complex macrosocial, cultural, environmental, political and other external factors that may influence environmental health behaviors at multiple levels of the socio ecological model (C. F. Clark, Kotchen, & Moore, 2003; Mancha & Yoder, 2015; Sniehotta, Presseau, & Araújo-Soares, 2014). Other criticisms are that the theory fails to thoroughly explore the root causes of beliefs; nor does it explicitly investigate non-voluntary factors that can affect behavioral intention such as power dynamics, trust relationships, and policy (Butterfoss & Kegler, 2012; Munro, Lewin, Swart, & Volmink, 2007). The individual behavior focus is of particular interest from an environmental justice perspective since individual prevention "does not address the historical and persistent disinvestment in urban infrastructure, especially in neighborhoods inhabited by low-income people and people of color" (Schwarz, Cutts, London, & Cadenasso, 2016). Another criticism is the that the TPB provides a static view of behavior change (Gebhardt & Maes, 2001).

Unlike stages-of-change theories, TPB constructs do not incorporate the varied levels of behavioral intention a person may exhibit over their lifetime. Others have critiqued the TPB since it doesn't account for "competing life demands" or directly provide communication intervention strategies for behavioral change (Glanz, Rimer, & Viswanath, 2015; Weinstein, 1988). Moreover, potential solutions to behavioral change for environmental health issues need to occur not only at the individual level, but also at social, community and policy levels. Solutions at the policy level might be more comprehensive and effective than at the individual level. For example, EPA policies to reduce emissions from coal-fired power plants in the U.S. may be more effective in reducing overall mercury atmospheric emissions than individual energy reduction behaviors. Moreover, this puts the solution burden on the individual despite the disproportionate impact of pollution by some industries. Despite these criticisms, researchers have utilized TPB to investigate many types of behaviors and have added constructs to the model to address social and external variables to behavioral change.

Study Significance: A Mixed Methods Approach

<u>Significance</u>

The United Nations Food and Agricultural Organization (FAO) estimates that 800 million people engage urban agriculture, and this number may increase with the worldwide expansion of urbanization and promotion of urban agriculture benefits (Badami & Ramankutty, 2015). In many U.S cities. and worldwide, there are no state or city policies that require school gardens or playground soils to be tested for heavy metals, thus vulnerable populations may be at risk to harmful soil exposures. Some community gardeners may be unaware of risks related to contaminated soils, methods to reduce exposure, and resources to address soil contaminant concerns. Significant knowledge gaps involve characterizing the complex factors that influence attitudes, social norms, perceived behavioral control, and risk perceptions related to soil contamination among community gardeners. Facilitators and barriers to employing soil testing and other best practices to minimize soil contaminant exposures may vary among different types of community gardens. Methods from the natural and social sciences can be used to investigate these concerns, but differences in epistemological frameworks and absence of community involvement can prevent effective application of research findings. Social and environmental health scientists need to collaborate with community gardeners to investigate and implement appropriate strategies related to soil contamination.

By building on the strengths of both behavioral and environmental health sciences, the goals of this research are 1) Identify community gardeners' perceived gardening benefits and risks as well as salient beliefs related to soil testing 2) Characterize gardeners' perspectives of best management practices (composting, mulching, and hygiene-related behaviors) to reduce soil contaminant exposures

3) Quantify the impact of attitudes, subjective norms, and perceived behavioral control on intention to soil test among U.S. community gardeners. This study can facilitate increased awareness of heavy metal soil contaminants as well as incorporate gardeners' perspectives on needs and solutions related to soil contamination. The outcomes of this study could be used to design targeted interventions, to inform soil testing policies, and to promote best management practices to mitigate exposure to soil contaminants among urban community garden stakeholders.

Approach

Mixed methods research incorporates qualitative and quantitative approaches to conceptualize, collect, and analyze data. The combination of these approaches provides a more holistic understanding of the research question than either approach individually (Creswell & Clark, 2011). The quantitative research paradigm is from an etic or "outsider" perspective ;however, qualitative research focuses on an interpretive paradigm with a focus on participants' perspective or the emic perspective (Hennink, Hutter, & Bailey, 2010). In the context of environmental health sciences, quantitative methods can indicate how often, how many, and to what extent a population has been exposed to an environmental pollutant. Qualitative methods can help to elucidate the context and processes that influence environmental health behaviors (Patton, 2015). Qualitative research methods have been employed in some environmental health studies to explain risk perception and behavioral change that may not be sufficiently described by a survey, biological, or environmental sample. For example, qualitative data can provide context to explore underlying factors that contribute to risk perception and behavioral change for environmental exposures (Hoover, Renauld, Edelstein, & Brown, 2015; Scammell, 2010; Silva, 2011).

Using the Theory of Planned Behavior as a conceptual framework (Figure 1.2), an explanatory mixed methods design was employed for this study consisting of the following: Formative Qualitative Research (Aim 1) and Survey Development & Analysis (Aim 2). Aim 1 was an elicitation study that utilized focus groups of Atlanta community garden leaders to explore beliefs related to practices to reduce exposure to heavy metal soil contaminants while gardening. Beliefs focused on consequences, social pressures, and barriers and facilitators of conducting the best management practices. Chapter 2 discusses specific beliefs related to community garden benefits, contaminant risk perception, and heavy metal soil testing. Chapter 3 highlights qualitative results related to composting, mulching, and hygiene related behaviors. Based on results from Aim 1, a survey was developed, pilot tested, and then administered to community gardeners across the United States through solicitation at the American Community Gardening Association Conference (Aim 2). Logistic regression with robust standard errors was implemented to quantitatively access which factors influenced gardeners' intent to test their soil (Chapter 4). Finally, Chapter 5 involves a summary discussion of triangulation of the focus group results with the survey data, conclusions, and public health implications.

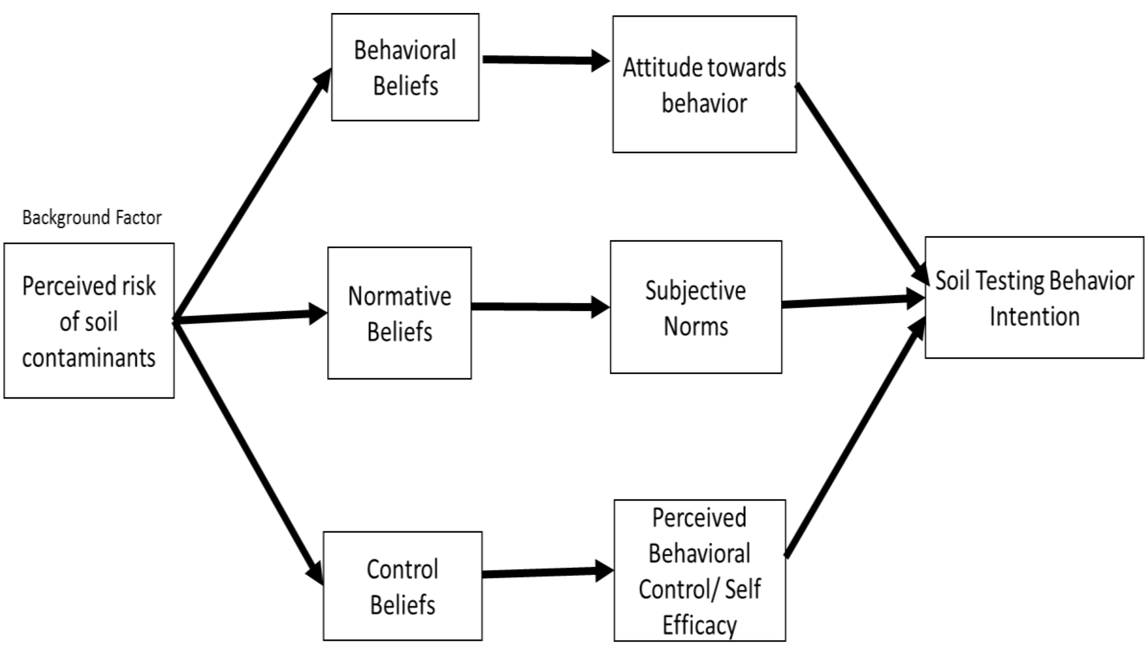

Figure 1.2 Study Conceptual Framework

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Chapter 2: A Qualitative Study of Atlanta Community Garden Leader Perspectives on Gardening Advantages, Heavy Metal Soil Contamination Risks, and Related Behaviors

For Submission to *Health Education and Behavior*

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Abstract

Community gardens offer numerous benefits, but there are also potential risks from exposure to harmful contaminants such as lead in the soil. Through the lens of the Theory of Planned Behavior, this study employed five focus groups to examine community garden leaders' beliefs regarding gardening hazards, heavy metal soil contaminants, local history, and testing soils for heavy metals in Atlanta, Georgia. Qualitative analysis of the focus group transcripts revealed that gardening benefits are perceived to be greater than any potential risks and that heavy metal soil contamination was not frequently identified as a common gardening hazard. Results also indicate that influencers regarding gardening hazards include gardening peers, government, university, and relevant advocacy organizations. Heavy metal soil testing was viewed as a tool to improve soil quality, and thus grow healthy food. However, awareness, accessibility, skepticism, and interpretation of results limited heavy metal soil testing in community gardens. Engaging diverse stakeholders to address knowledge gaps, beliefs, challenges, and facilitators of gardening risks identified in this study could improve community garden interventions and educational efforts to address soil contamination.

Introduction

Community Garden Soil Contamination

Community gardens are operated by community members to cultivate produce (Guitart et al., 2012; Pudup, 2008) and can occur in multiple contexts including neighborhood, school, workplace, faith communities, hospitals, senior homes and prisons (Draper & Freedman, 2010). Community gardens differ from private and home gardens in that they typically involve a form of community guardianship, access, and degree of self-governance (Ferris et al., 2001). Community gardens are proliferating across America: from 2008 to 2013, the number of households in the United States participating in community gardens has increased from one million to three million (National Gardening Association, 2014). In Atlanta, Georgia, there are at least 300 community gardens in the 10-county metropolitan region that serve an estimated 7,000 residents (Foodwell Alliance, 2017). Research has shown that community gardens provide many health, social, educational, environmental and economic benefits (Al-Delaimy & Webb, 2017; Litt et al., 2015; Litt et al., 2011). However, to maximize these benefits, it is important to know and, if needed, mitigate the risks of exposure to soil contaminants. Gardeners may be exposed to contaminated soils through ingestion of soil particles and dust through gardening activities; tracking contaminated dust and soil in the home; and consumption of unwashed produce (Kessler, 2013). Although several studies have quantified soil contaminant concentrations in urban gardens (Antisari, Orsini, Marchetti, Vianello, & Gianquinto, 2015; Chammi P Attanayake et al., 2014; H. F. Clark, Hausladen, & Brabander, 2008; Defoe et al., 2014; M. B. McBride et al., 2014; Mielke, Gonzales, Powell, & Mielke, 2013; Mitchell et al., 2014b), understanding gardeners' beliefs and perceptions are critical to the development of interventions that abate these risks.

Soil Testing in Urban Community Gardens

Many organizations have recommended strategies to prevent and minimize exposure to soil contaminants in urban gardens. Best management practices to reduce exposure to contaminants in urban gardens include conducting a garden site history and soil testing (S. L. Brown et al., 2016; Kessler, 2013; Mitchell et al., 2014b; Scheckel et al., 2013; U.S. Environmental Protection Agency, 2011). Conducting a site history will elucidate the previous land use and can help identify targeted soil testing and potential areas of concern. Soil testing provides baseline measures of the soil quality and can quantify contaminant levels of heavy metals such as lead, cadmium, and arsenic. In the urban environment, sources of these heavy metals may include run-off and particles from heavily trafficked roadways, industrial facilities, contaminated building materials and compost, and older (pre-1978) housing and buildings (Mitchell et al., 2014b).

Despite these recommendations, gardeners may not test their soils or research their gardens' site history. According to a survey of Atlanta community gardeners (n=175), 63% had their soil garden soil tested for pH or micronutrients within the last 3 years (Foodwell Alliance, 2016). However, only 11.5% of gardeners had their soil tested for contaminants such as heavy metals. A gap in the literature exists that further explains this discrepant behavior. This current study seeks to fill this gap and better understand this low testing percentage, by identifying the barriers and facilitators of heavy metal soil testing as well as perspectives on gardening hazards and soil contaminants.

Risk Perception of Soil Contaminants

Several studies indicate that community gardeners in urban environments exhibit minimal concern and varied knowledge about soil contaminants, site history, and methods to reduce exposure to soil contaminants. To understand community gardeners' views and knowledge of soil contamination, researchers administered surveys to 70 gardeners and 18 community garden key informants in Baltimore, Maryland. Findings from this research suggested that gardeners were often unaware of some soil contaminants and methods of reducing exposure. Additionally, barriers such as cost and complicated processing deterred gardeners from testing their soil and identifying the site history (B. F. Kim et al., 2014). A study of urban gardeners in Missouri and Washington, revealed that over 50% of the respondents reported that they were unaware of how to detect the presence of soil contaminants in an urban environment and where to send their soils for sampling (Harms, Presley, Hettiarachchi, & Thien, 2013). Another survey of 20 community gardens in Missouri indicated that most gardeners were not concerned about soil contamination, but black gardeners, in particular, were more likely to be concerned about soil contamination(Wong, Gable, & Rivera-Núñez, 2018). Focus group findings from an urban agricultural study in Ohio among low-income residents conveyed a need for more information about soil quality, soil testing, remediation, and garden startup costs (M. L. Kaiser, Williams, Basta, Hand, & Huber, 2015a).

Most U.S. studies on gardeners' attitudes and knowledge related to soil contamination have been conducted in states with large urban cities in the Northeast, Midwest and West, with fewer published studies in the South. Additionally, several of these studies did not employ a theoretical lens to examine underlying beliefs related to gardeners' perspectives.

The Theory of Planned Behavior (TPB) serves as the underlying theory for this study (Figure 1) and provides a conceptual framework to understand behavioral intentions and to identify actionable intervention targets. The premise of the TPB is that behavioral intention is a primary predictor of behavior and is strongly and positively correlated with performance of a particular behavior (I Ajzen, 1991). In this study, the behavior of interest is soil testing and the TPB is being used to better understand the perceived likelihood or readiness of participants to perform soil testing. In the application of this theory, the three primary predictors of soil testing intention include: Attitude, Subjective Norms, and Perceived Behavioral Control. According to the TPB, it is then hypothesized that perceived behavioral control and higher favorability of attitudes and subjective norms will lead to soil testing intention (I Ajzen, 2002; Montano & Kasprzyk, 2015).

Behavioral beliefs are underlying convictions that the behavior will produce a given outcome (e.g., soil testing will detect potential soil problems; soil testing will result in liability concerns), and behavioral beliefs precede the attitude toward the behavior. Normative beliefs are perceived behavioral expectations of referents (e.g., other gardeners, environmental organizations). Control beliefs are beliefs about the presence of factors that may serve as barriers or facilitators to performing the behavior (e.g., soil testing is expensive, soil testing is too complicated).

This study sought to examine behavioral, normative and control beliefs related to heavy metal soil testing among Atlanta community garden leaders. Primary research questions included: 1) What are community garden leaders' beliefs regarding the likely consequences of conducting soil contamination testing? 2) What are community garden leaders' beliefs related to perceived social pressures that may influence soil testing? 3) What do community garden leaders perceive to be barriers and facilitators that contribute to whether gardeners seek soil testing? In addition to these primary research questions, the study also explored community garden leaders' thoughts about community garden benefits, hazards, perceived risks, and garden site history.

Methods

Study Participants

Purposeful sampling techniques were used to recruit for the focus groups (Hennink et al., 2010). The aim was to recruit gardeners from different garden contexts and locations who had varying soil testing experiences. Focus group participants were recruited via email solicitation utilizing listservs from community garden and environmental organizations. To be eligible to participate in the focus group, community garden administrators/leaders had to be at least 18 years of age and involved at their present community gardening site in five metropolitan Atlanta counties (Clayton, Cobb, DeKalb, Fulton, and Gwinnett) for at least 3 months. Potential participants were emailed a survey to ensure their eligibility status. In the eligibility survey, gardeners were asked to share their garden context (e.g., neighborhood, park, school, faith-based, senior-center, healthcare facility), community garden county location, focus group availability times, and whether they had previously tested their garden soil.

As an incentive for focus group participation, potential participants were offered a free heavy metal soil screening (valued at $35), interpretation of soil screening results, and resources for more information to reduce exposure. Participants were provided instructions and technical assistance on how to collect their soil samples, and they brought their soil samples to their respective focus group session. Focus group participants also received a gardening gift consisting of gloves, trowel, seeds, and best practices information on reducing exposure to soil contaminants in urban environments.

Ethical Consideration

The research protocol was reviewed and determined exempt by Emory University Institutional Review Board.

Data Collection Procedures

Focus group participants completed a consent form prior to beginning the focus group, and a short survey at the end of the focus group discussion. The survey included questions regarding demographic and garden context. To guide the focus group discussion, a semi-structured discussion guide based on TPB guidelines (Francis et al., 2004) was developed to cover topics such as beliefs and risk perception related to soil contamination (Appendix A). The focus group moderator first welcomed the participants, introduced the purpose of the focus group, and then explained the focus group process. Focus groups were facilitated and audio recorded by the first author (C.H.). The focus groups were conducted at quiet meeting rooms at Atlanta libraries and county Extension conference rooms.

Data Analysis

Focus group recordings were transcribed verbatim, and a code book was developed based on TPB research questions (deductive codes) and salient themes from the focus group transcripts (inductive codes). Two analysts independently reviewed and coded the focus group transcripts. Intercoder agreement was established by comparing the independently coded transcripts and resolving any coding discrepancies through discussion. The coded themes (nodes) were entered into NViVo 10 (QSR

International Pty Ld, Melbourne, Australia), and content analysis was performed using NVivo summary reports by Node output to identify themes and patterns based on the primary research questions. Primary themes and summaries were based on frequency of mentions and consistency across focus groups. Descriptive data from the community garden survey were analyzed using STATA 15 (Statacorp LP, College Station, Texas, 2009).

Results

Focus Group Participant and Community Garden Characteristics

Twenty-six gardeners representing community gardens in Cobb (23%), DeKalb (30.8%), Fulton (30.8%), and Gwinnett (15.4%) Atlanta-metropolitan counties participated in one of five focus groups from February to March 2017. Focus groups ranged in size from four to eight participants, and the focus group discussions ranged from 75 to 90 minutes. As shown in Table I, most focus group participants were female (76.9%) and identified as non-Hispanic/Latino (88.5%), white (69.2%), or black (26.9%). Most of the focus group participants were 35 years or older (84%; 40% between the ages of 36-55) and had at least some college education (96%). Most of the focus group participants were community garden leaders (n=21, 80%) and had previously participated in a gardener training (79.2%).

Most participants identified their community gardens as neighborhood gardens (57.7%), with raised beds (80.8%), and in operation for at least 6 years (60%) (Table II). Almost all gardeners indicated that they knew at least something about the previous land usage of their community gardens. Regarding their community gardens' soil, 58% indicated that soil had been previously tested. Of the 14 participants who had previously tested their soil, only one had tested for heavy metals, 13 (86.7%) had tested pH, and 15 (88.2%) had tested for nutrient content (e.g. phosphorus, potassium).

Community Garden Benefits

When describing their community garden, focus group participants frequently expressed that the garden provided benefits such as positive engagement of different generations, economic backgrounds, and vulnerable populations (e.g., handicapped, ex-cons). For example, one gardener expressed:

> "*We have everything you can imagine in our neighborhood, including USDA food desert, although we do have a gated community as well…gardening is such a great way to bring people together from all different cultures and socioeconomic levels…. we have people from all sections of the community that come and garden together"*

In addition to community engagement, other community garden benefits mentioned were donating produce to food insecure communities, serving as a great educational tool for children, and facilitating a spirit of community. One African-American gardener also expressed that gardens can serve as an instrument to teach others, retain cultural identity, and build a sense of kinship and active collectivism:

> *"I'm trying to retrain my people, meaning folks that look like me, Black Americans, to get back into that village mentality where you just take what you need and leave for others, and share in the work…because we've been put into a society that's very individualistic, and that's been harmful for our communities to become individualistic, because we're not looking out for each other"*

Another gardener mentioned that gardens may promote environmental stewardship and awareness even outside of the garden.

> *"[Community gardening] increases their awareness of the relationship to the Earth, and I think it promotes recycling amongst our gardeners, like in their home life … it just brings it to their awareness and makes them more prone to recycle and reuse"*

Gardening Hazards and Risk Perception

Participants described where they received information about various hazards while gardening. The most frequently mentioned sources were from other fellow gardeners and farmers (particularly peers from training programs), followed by the Extension Office. Other information sources included university websites, social media, online forums, internet searches, and health departments. Participants shared that events (e.g., training activities, workshops) and information (e.g., newsletters, flyers) provided by their community garden were very influential.

Participants then discussed the types of hazards encountered while gardening. The most frequently reported hazards were physical which included pests (e.g., fire ants, insects, snakes), proper tool handing, heat stress/proper hydration, broken glass and other debris. Ergonomics and proper tool usage were cited as safety factors. Security concerns such as being alone in the garden, theft, and vandalism were often mentioned. For example, one focus group participant shared:

> *"We do have a number of potential hazards…sharp items like tools, bee stings, fleas, spiders, fire ants, mosquitoes pose an interesting problem because of West Nile. Vandalism or people unknown walking into the garden when someone is alone. That's a concern that we have a sensitivity about."*

Another participant expressed the following safety concern: "*We're in a high crime area, and so we've had thefts in the garden… there's drug deals and stuff that go on across the street, and so a lot of our gardeners are wary about being there alone or being there at dusk."*

Participants also mentioned biological hazards such as Mosaic virus, fungus, and pet waste. One participant stated, "*I've always been aware that if a cat was to defecate in your bed, there is a bacterial disease that you can get, so I've just always tried to be careful about that…. There are bacteria that wouldn't sit well with our digestive systems, so I just try to be aware of that and wash things carefully."*

For chemical hazards, participants discussed varying levels of concern and risk perceptions. Some participants indicated that chemical hazards are not a strong concern compared to other hazards. These participants stressed that most gardeners think that gardening benefits outweighed any potential risks. One participant expressed, *"I don't think they worry about heavy metals. I worry about heavy metals, but I don't think they do, and they're interested in what do I need to add to make this soil healthier so I can grow vegetables."* Among gardeners who expressed that they had strong knowledge of the garden site history and extensive gardening experience, potential chemical contaminants were not cited as a relevant concern. For example, a focus group participant that was also a Master Gardener stated, *"I don't think anybody in my area is worried about [chemical hazards], because we've been at the same site for 60 years."*

Of the participants that expressed concerns about chemical hazards, they were most often associated with previous site use, chemical spraying, wood chips, flooding, and water pollution. For instance, a participant shared: *"…the neighborhood garden I work with is actually almost on a traffic island, so there's concern about run off from the roads and what might get sprayed by city vehicles."* Another participant emphasized, *"There has been a concern in urban areas where they're putting gardens in, like where businesses or structures were torn down, because there's possibility of lead contamination or other metals."*

Although the community gardener participants mentioned that they would prefer to abstain from using chemicals when gardening, there was concern about enforcing pesticide/spraying ban among other gardeners or neighbors. A participant who also serves as a county Extension service agent shared *"The problem is most of them don't even think about it [chemical hazards], so I discourage people from growing anything around the perimeter of the house, because that is where the pest control person comes and puts all the various chemicals all around your house."*

Site History

After probing questions about their garden and potential gardening hazards, garden site history was recurrently discussed. A few participants expressed that they had thorough knowledge about previous activities that had taken place on their garden land and used Sanborn maps to identify previous owners/site use. For example, a gardener knowledgeable of their garden's property expressed:

"I've been going by the property for 40 years and there weren't any crops growing there then, but I don't know that there's ever been anything in the last 100 years there that would be harmful. When we do gardening in our raised beds, we buy soil and fill in there, so we don't even think about poisons in the soil because we pretty much know that we're getting fresh soil and it's good soil"

Other gardeners did not know or were unsure about previous site use, and they expressed concerns about historical industrial activity, dumping of gasoline and other hazardous materials, flooding, and downstream run-off. One gardener expressed that some gardeners may be more vigilant about current hazards than past hazards: "*They think a lot about what they or the other gardeners could put on the site, but they don't think about what's already on the site."* Another gardener expressed concerns about persistent chemicals due to spraying at former farm properties: "…*those were old farm sites and people don't think about the arsenic that was in the soil, and we have tested some of our partner sites and they had arsenic in them, because arsenic was used to treat cotton pests...And it doesn't go away. It's there a long time."*

Soil Testing

Behavioral Beliefs

Advantages of soil testing included early identification of soil quality problems, ability to take appropriate actions in advance, and peace of mind. One participant shared: "*I think if you know what's there, it lets you know if there's a problem that you might want to deal with in terms of heavy metals and* *pesticides…If you know what's there in terms of the nutrients, then you've saved yourself money by not over fertilizing.*" Other advantages were verifying soil quality from purchased or donated soil, satisfying soil certification needs (e.g., USDA organic, natural), and saving time and money on soil treatment and amendments. One participant expressed that they would like to get soil testing because *"I am not aware of where the dirt came from, so I don't know what's in it."* Another participant added, "*And then there's the added thing of you know when your soil is out of whack and your vegetables aren't growing right…so you avoid the problem by starting out right with knowing what's in there."*

Primary soil testing disadvantages were concerns about liability if high levels of contaminants were discovered and associated costs (e.g. remediation, soil replacement, shutting down garden), fear of scaring people away from gardening, and perceived lack of need. One gardener declared, "*Because a lot of people, well, my plant's growing, why should I test the soil?"* Another gardener shared liability concerns and that raised beds may preclude the need for soil testing:

"I think it might cause some fear in your everyday gardener to not rent a bed if they felt like there was danger that it had toxins or metals in it…if we didn't reassure them that raised beds have clean soil from a good source… it might deter some people from renting a bed, which we -- like many gardens, are sustained by renters "

The time and resources needed to collect, ship, and receive sample results were discussed as disadvantages. Additionally, some gardeners expressed concerns about the accuracy, specificity, and sensitivity of the soil test results and soil sampling techniques. A gardener who had their soil previously tested for heavy metals stated:

"I wondered just how accurate the test results would be, like maybe whatever heavy metal was pooling in my soil, pooling in an area that I didn't sample, and then do I have sort of a false positive"

Another participant followed up with the uncertainty about the soil sampling techniques used for testing by sharing *"And then even with the sampling, will that sampling really be representative?"*

Normative Beliefs

Participants stated that supporters of soil testing would be environmental groups (e.g., Sierra Club, Kiwanis Club), other gardeners, Extension Service/Master gardeners, Parks Department, school administrators, parents, government agencies, and gardening experts. Participants also mentioned that gardening training programs and food advocacy groups (e.g., Truly Living Well Center for Urban Agriculture, Georgia Organics, Georgia Farmer's Market Association) would be strong supporters of heavy metal soil testing. Non-supporters of soil testing mentioned were experienced gardeners knowledgeable of site history and practices, chemical companies, landowners, and stakeholders concerned about property values. Another sentiment was that non-supporters may think that testing may result in unwarranted anxiety and waste of resources. One participant stated, "*I think there are some people who feel that it would test everything, we worry too much about everything, and end up spending money on things rather than just getting on with it."*

Control Beliefs

Facilitators of soil testing were lowering costs, increasing accessibility, desire to understand soil quality, and increased educational outreach on where to send samples, how to collect samples, and interpret soil testing results. Participants suggested that clearer language regarding the soil testing results, level of uncertainty about the results, and guidance on next steps after testing would encourage gardeners to test their soil. Additionally, having supplies available on site to collect and ship samples would simplify the process. To facilitate soil testing, participants recommended that gardening training include a stronger emphasis on soil testing and site history knowledge. Moreover, recruiting groups to collect samples as part of a volunteer or garden project would be beneficial. For example, a participant shared

"But one more thing about encouraging this sampling, you could have sort of a formal thing. Anybody who wants to do it, we'll all do it together at the same time during the work day, and then somebody can take the samples over."

Another participant within the same focus group emphasized this point with *"I think if you have it as a group, we have some high school students who volunteer at our garden. I wanted to do a soil sample of a bed, and so I got the kids to do it so that they could learn about soil testing. I gave them the bags because they also volunteer at other gardens in the community"*

Soil testing barriers included cost, time, accessibility, and lack of knowledge regarding where to get samples tested, how to collect samples, and how to interpret the results. Regarding soil test results, one community gardener stated, *"They give you parts per million and a lot of times there's not a definite level that's acceptable, because nobody really knows how much is acceptable, so they'll say it's EPA limits or below EPA limits or something, but you still don't know if that's safe."* Fear of unnecessarily alarming gardeners came up again as a barrier to testing, with a participant sharing "*but you've got to be careful not to scare and upset people unnecessarily, because sometimes these things with the environment get blown way out of proportion*."

Discussion

Using the TPB as a theoretical framework, this study explored Atlanta community garden leaders' experiences and beliefs regarding garden benefits, risk perception of garden hazards and heavy metal soil contaminants, site history, and soil testing. The qualitative design of this study allows for characterizing the underlying beliefs that influence community gardener behaviors and motivations. Consistent with other studies (Al-Delaimy & Webb, 2017; Katherine Alaimo, Alyssa W Beavers, Caroline Crawford, Elizabeth Hodges Snyder, & Jill S Litt, 2016b), gardeners collectively articulated perceived social, educational, and environmental benefits of community gardening. Of note was that some of the perceived community gardening benefits were assumed to translate beyond the garden environment such as building community relationships, strengthening cultural identity, and environmental stewardship. For most gardeners, the benefits of gardening heavily outweighed any potential gardening hazards.

This study also provided data on information sources and perceived community gardening hazards. Focus group participants shared that they received most of their information about gardening hazards from their gardening peers, Extension Service, various non-profit organizations, and their community garden training events and outreach activities. Gardeners frequently cited physical hazards and safety concerns such as theft and vandalism. It is important to emphasize that these physical hazards were perceived as more common and dangerous threats than biological or chemical hazards. A few gardeners cited chemical hazard concerns related to pesticides and other chemicals (e.g., lead, arsenic) that could be currently sprayed at their garden site, translocate from nearby sites, and/or contaminate soil from known and unknown historical site activities. Experienced gardeners that were informed of their garden's site history seemed less concerned about chemical hazards than novice gardeners. Gardeners who expressed concerns about past dumping and other land use activities at their garden site were unsure of how to research whether these activities had happened.

This study systematically investigated specific behavioral, normative, and control beliefs about heavy metal soil testing using a behavioral-theory based approach. By understanding these beliefs, more informed soil testing interventions may be implemented. A primary behavioral belief for the advantage of soil testing was improving soil quality to grow healthy, safe food. Most of the focus group participants had previously tested their soil for pH and nutrients, but not heavy metals. Many participants were aware that the Extension Service conducted pH and nutrient testing, but some were unaware that they also conducted other types of soil testing. Disadvantages of soil testing were perceived lack of need, resources, and liability concerns. Because soil testing contaminant thresholds and follow up actions may vary by jurisdiction, development of clear guidelines and interpretation of soil testing may combat uncertainties and consequences of testing. Due to having raised beds with imported soils, several gardeners expressed that their soil did not need to be tested. Installation of raised beds and filling of beds with clean/tested materials may reduce some potential soil contaminant exposures; however, raised beds cannot prevent windblown dust or other airborne contaminants, particularly if gardens are located near heavily trafficked roadways (H. F. Clark et al., 2008).

Potential supporters of soil testing included environmental groups, other gardeners, and gardening training programs. Reducing barriers to heavy metal soil testing such lowering costs, increasing accessibility, and providing guidance on test interpretation and next steps were cited as methods to encourage soil testing. Onsite technical assistance, assessment, and education about present and past sources of gardening hazards (particularly contaminants) by trusted sources could facilitate a stronger interest in potential chemical contaminants.

There are several limitations of this study. First, the study focus group participants may not be representative of the demographics of Atlanta metropolitan gardeners. Our participants may represent a more self-motivated subset of our population with a higher affinity to health–related topics, and consequently, have generally different sentiments regarding the study questions than those who did not participate. Most participants were community garden leaders that had some training and may not reflect the perspectives of novice community gardeners. Secondly, focus groups may have the potential to invoke information bias if the group is swayed by the moderator or if there's deference to perceived dominant participants. For example, some participants may have had deference to the Extension agents and Master Gardeners in the focus groups. Additionally, social desirability bias can occur when focus group participants give responses that they believe the group feels are acceptable instead of responses based on their true feelings and experience. Lastly, the soil screening incentive may have inadvertently influenced participants' responses regarding soil testing and impacted their decision to participate in the study.

Despite these limitations, this study has meaningful implications for outreach regarding gardening risks and safety interventions. First, this study suggests that emphasis on soil health/quality to grow healthy food may strongly resonate with gardeners. Therefore, messaging about heavy metal soil testing could be framed as an integral component of understanding other soil quality characteristics that gardeners are familiar with such as soil texture. Second, this study identified referents (e.g. environmental groups, gardening training programs) and information sources that could influence some gardeners' perceptions of gardening hazards and soil testing. Through targeted educational outreach, these referents and information sources can help increase awareness of soil contamination risks, site history, and soil testing. Finally, the study results illustrate potential opportunities for reducing identified barriers such as challenges with soil sample collection for testing and results interpretation. For example, universities, citizen-scientists, and other organizations have collected soil samples and provided information on the results (Ramirez-Andreotta, Brusseau, Artiola, Maier, & Gandolfi, 2015; University of North Carolina Superfund Research Program Translation Core (RTC), 2016; Vaouli & Pomales-Schickli, 2015).

Conclusion

By using a TPB theoretical framework, this paper contributes to the literature regarding factors that could facilitate or impede adoption of behaviors to protect community gardeners from harmful exposures in a southern urban area. To increase environmental health literacy about soil contaminants, numerous soil safety resources have been developed and disseminated by nonprofit organizations, Extension services, and government agencies. These environmental health promotion activities may potentially improve gardeners' knowledge and awareness about reducing exposure to soil contaminants; however, these activities alone may not fully address facilitators and barriers to adoption of safe gardening behaviors. Studies have demonstrated that information and environmental health literacy alone cannot change environmental health related behaviors (Gifford & Nilsson, 2014; Pilling et al., 2008; Stern, 2011). By addressing the underlying beliefs as well as the barriers and facilitators identified in this study, stakeholders may be able to develop more targeted community garden interventions and educational efforts.

Future research could involve survey development based on primary themes identified in this study as well as analysis of demographic and garden contextual factors that may influence risk perceptions, soil testing, and perceived community garden benefits. Identifying risk perceptions, social norms, and potential obstacles for implementing environmental policies is an important initial step in developing effective interventions (Lobdell, Gilboa, Mendola, & Hesse, 2005). Additionally, qualitative studies of other community garden stakeholders (e.g. food insecurity intervention organizations, local government agencies, and early childhood education programs) can help determine other contributors to healthy soil training and testing policies while also promoting access to safe, healthy food sources (D. Smith, Miles-Richardson, Dill, & Archie-Booker, 2013). Policies developed in Baltimore, Portland, Chicago, and New York City require soil testing prior to redevelopment of lands for agricultural and community garden purposes (Goldstein, Bellis, Morse, Myers, & Ura, 2011b). Evaluation of the public health benefits and enforcement strategies of these policies may aid other urban cities with community gardening and urban agriculture growth.

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Table 2.1: Focus Group Participant Demographics

Garden Role	**N(%)**
Community Garden Leader	21(80.8)
Gardener/ Garden plot owner	1(0.04)
Volunteer	3(0.12)
Other	1(0.04)
Garden Training	
No	5(20.1)
Yes	19(79.2)
Age	
18-35	4(16.0)
36-55	10(40.0)
56-65	5(20.0)
66-75	6(24.0)
Gender	
Female	20(76.9)
Male	6(23.1)
Ethnicity	
Hispanic/Latino	3(11.5)
Not Hispanic/Latino	23(88.5)
Race	
American Indian or Alaska Native	0(0.0)
Asian	0(0.0)
Black or African American	7(26.9)
Native Hawaiian/ Other Pacific Islander	0(0.0)
White	18(69.2)
Bi-racial	1(3.9)
Highest Level of Education	
Some High School, High School Graduate or less	0(0.0)
Vocational/Technical School	1(4.0)
Some College	2(8.0)
University/College Graduate	14(56.0)
Graduate School or Higher	8(32.0)
Annual Household Income	
Less than $24,999	4(17.4)

$25,000 to $49,999	6(26.1)
$50,000 to $99,999	7(30.4)
$100,000 or more	6(26.1)

Table 3.2: Focus Group Participants' Community Garden Information

Garden Type	**N(%)**
Neighborhood	15(57.7)
Park	6 (23.1)
School	2(.08)
Faith-based	1(.04)
Senior Center	1(.04)
Other	1(.04)
County	
Cobb	6(23.1)
Dekalb	8(30.8)
Fulton	8(30.8)
Gwinnett	4(15.4)
Garden Structure*	
Raised Bed	21(80.8)
Directly In Ground	14(53.9)
Site History	
Vacant lot	6(23.1)
Park	3(11.5)
School	2(7.7)
Former Residential area (e.g., house, apartment)	6(23.1)
Farm	2(7.7)
Don't Know	4(15.4)
Other (e.g., playground, undeveloped area)	3(11.6)
Years of Garden Operation	
Less than a year	2(8.0)
1-5 years	8(32.0)
6-10 years	12(48.0)
Greater than 10 years	3(12.0)
Number of Gardeners	
Less than 5	4(16.0)
6-15	2(8.0)
16-30	4(16.0)
Greater than 30	15(60.0)
Any type of Soil Test	
Yes	14(58.3)

No	10(41.7)
Skipped	2(8.0)
Heavy Metal Soil Test	
Yes	1(6.3)

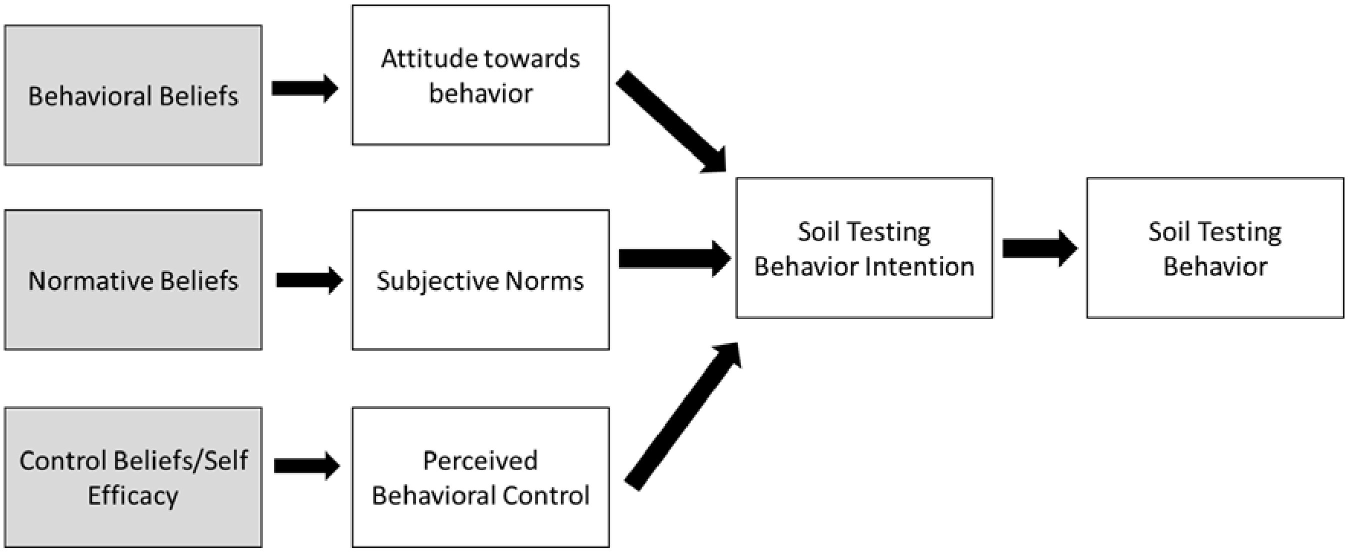

Figure 3.1: Theory of Planned Behavior- Study Conceptual Framework for Soil Testing

***Shaded boxes indicate topics examined in this study**

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Chapter 3: Safe Community Gardening Practices: Focus Groups with Atlanta, Georgia Garden Leaders

For submission to *Local Environment*

Abstract

Although best management practices have been recommended by government agencies and non-profit organizations to reduce community gardeners' potential exposure to soil contaminants such as lead, some gardeners do not perform these practices. Understanding gardeners' beliefs and motivations is critical for effective promotion of safer gardening practices. This study, grounded in the Theory of Planned Behavior (TPB), employed five focus groups to investigate Atlanta community garden leaders' perspectives concerning three gardening practices: composting, hygiene behaviors, and mulching. These practices are also considered safe gardening practices in that they can reduce exposure to toxicants in urban gardens. Qualitative analysis identified advantages and disadvantages; supporters and non-supporters; and barriers and facilitators that might influence gardeners' opinions regarding these behaviors. Gardeners expressed that more funding, volunteers, and training are needed to promote these behaviors. Gardeners noted that mulch and compost provided advantages such as improving soil quality, but a primary barrier was concern about contamination of source materials. Focus group participants did not directly associate composting and mulching with reduction of exposure to soil contaminants. Behavioral challenges related to hygiene included concerns about decreased exposure to salubrious bacteria, inadequate access to potable water, and limited availability of gloves and wipes.

Keywords: community gardens; urban agriculture; soil contaminants; environmental psychology; Theory of Planned Behavior

Introduction

Community gardens promote social capital (Katherine Alaimo et al., 2010; Firth, Maye, & Pearson, 2011), food justice (Horst, McClintock, & Hoey, 2017), increased access to and consumption of nutritious foods (K. Alaimo et al., 2008; Algert, Baameur, & Renvall, 2014; Litt et al., 2011), environmental sustainability (Holland, 2004; Okvat & Zautra, 2011), and provide many other benefits (Al-Delaimy & Webb, 2017; Katherine Alaimo et al., 2016a; Draper & Freedman, 2010; Laycock Pedersen & Robinson, 2018; Santo, 2016). In many areas of the United States, vacant lots and brownfields have been revitalized into spaces for community gardens and urban agriculture, providing increased access to healthy foods; offering job and training opportunities; promoting social cohesion; and fostering community empowerment (Drake & Lawson, 2014; Greever-Rice; McClintock, Cooper, & Khandeshi, 2013; M. M. White, 2011). In Atlanta, GA, recent initiatives to support urban agriculture have strengthened with the implementation of an urban agriculture ordinance, the appointment of the first Urban Agriculture Director in the U.S, and the development of the AgLanta "Grows-A-Lot" program to promote urban gardening and farming on city-owned vacant lands (City of Atlanta Mayor's Office of Resilience, 2018). However, gardening on vacant lots and other urban areas may also present environmental health risks such as potential exposure to legacy contaminants in the soil (Al-Delaimy & Webb, 2017; Mitchell et al., 2014b; Wortman & Lovel, 2013). Several studies have demonstrated that heavy metals such as lead and cadmium can exceed safe concentrations in urban community garden soils (H. F. Clark et al., 2008; Clarke et al., 2015; M. A. S. Laidlaw, Alankarage, Reichman, Taylor, & Ball, 2018; M. B. McBride et al., 2014; Mitchell et al., 2014b; Witzling, Wander, & Phillips, 2010). Exposure to these chemicals has been associated with adverse health outcomes, particularly among vulnerable populations such as children (Calderon et al., 2001; Cao et al., 2016; Ciesielski et al., 2012; M. A. Laidlaw et al., 2016; Moya, Bearer, & Etzel, 2004; von Ehrenstein et al., 2007).

Best management practices to reduce exposure to contaminants in urban gardens include: 1) conducting a garden site history; 2) locating gardens away from heavily trafficked roadways and older buildings; 3) testing soil; 4) installing raised beds; 5) amending soil with phosphorus and compost; 6) mulching to cover bare soil; and, 7) implementing proper hygiene behaviors (S. L. Brown et al., 2016; Hannick, 2016; Kessler, 2013; Mitchell et al., 2014b; Scheckel et al., 2013; U.S. Environmental Protection Agency, 2011, 2014). The first four behaviors are optimally conducted at the beginning of garden installation, although soil testing is appropriate both prior to garden installation and during garden maintenance. The last three behaviors (composting, mulching, and hygiene) are typically implemented during garden maintenance, often for advantageous results that may be unrelated to reducing toxicant exposures.

While these three behaviors may be implemented to obtain other beneficial gardening outcomes, they are considered safe-gardening behaviors because their implementation can reduce toxicant exposures. For example, chemicals in soil amendments such as phosphorus fertilizer and compost may bind to toxicants in soil to decrease their soil mobility and bioavailability (Chammi P Attanayake et al., 2014; Attanayake, Hettiarachchi, Martin, & Pierzynski, 2015a; S. Brown et al., 2003; Park et al., 2011; Scheckel et al., 2013). Covering bare garden areas with mulch can minimize exposure to windblown contaminants (Kessler, 2013). Lastly, hygiene practices, which include wearing gloves, leaving gardening shoes and gear outside, thoroughly washing hands and produce, and peeling produce, can limit direct contact with potentially contaminated soil (U.S. Environmental Protection Agency, 2011).

Extension County Offices, government agencies, universities and non-profit organizations have conducted activities such as training, outreach, and distribution of factsheets and other informational materials to promote the adoption of safe gardening practices among community gardeners and other farmers (Ramirez-Andreotta et al., 2015; Rouillon, Harvey, Kristensen, George, & Taylor, 2017; U.S. Environmental Protection Agency, 2011; Vaouli & Pomales-Schickli, 2015; Witzling et al., 2010).

However, community gardeners have varied knowledge, challenges, and concerns about soil contaminants and may fail to implement safe gardening practices that could minimize contaminant exposures (A. Chaifetz et al., 2015; Henson, Tenorio Fenton, & Tikalsky, 2017; B. F. Kim et al., 2014; Wong, Gable, & Rivera-Núñez, 2017). Several studies have illustrated that increased educational outreach and knowledge alone are not sufficient to change environmental health-related behaviors (Gifford & Nilsson, 2014; Pilling et al., 2008; Stern, 2011). Understanding a broader range of factors that influence behavior is essential to constructing safe interventions for gardeners and other growers (Marine, Martin, Adalja, Mathew, & Everts, 2016; J. M. Soon & R. N. Baines, 2012; Tobin, Thomson, LaBorde, & Radhakrishna, 2013).

The Theory of Planned Behavior (TPB) is a useful framework for assessing beliefs that influence environmental (Staats, 2003) and health-related (McEachan et al., 2011) behaviors. The TPB proposes that attitude, subjective norms, and perceived behavioral control are primary determinants that influence an individual's intention to conduct a behavior (I Ajzen, 1991). Underlying these three determinants are corresponding beliefs salient to behavioral intention: behavioral, normative, and control beliefs. Behavioral beliefs are underlying positive or negative convictions that the behavior will produce a given outcome, and behavioral beliefs serve as an antecedent of the attitude toward the behavior. Normative beliefs are perceived behavioral expectations of referents or the social forces that may influence behavior. The opinions of referents may promote or discourage specific behaviors. Control beliefs are beliefs about the presence of factors that may serve as barriers or facilitators to performing the behavior. Thorough investigation of these beliefs related to adoption of safe gardening activities can serve as the basis for targeted interventions to reduce potential soil contaminant exposures.

Qualitative research methods can elucidate the context and processes that affect behaviors which may not be sufficiently described by a survey, biological assessment, or environmental sample (Patton, 2015). Investigating the meaning and experience of environmental and protective behaviors may be better explored through qualitative methods such as focus groups, semi-structured interviews or key informant interviews (Lobdell et al., 2005; Scammell, 2010). Focus groups are effective in identifying intangible influences such as social norms, and the group interaction may provide richer information on social norms than individual interviews. This study utilized focus groups to explore the advantages and disadvantages (related to behavioral beliefs), supporters and non-supporters (related to normative beliefs), and facilitators and barriers (related to control beliefs) for the following soil contamination mitigation behaviors: composting, hygiene habits, and mulching.

Methods

Five focus groups including 26 Atlanta metropolitan area community garden leaders were conducted from February to April 2017. To recruit the focus group participants, purposive non-random sampling (Krueger, 2014) was employed through email solicitation of prominent Atlanta, Georgia community gardening organizations, food advocacy groups, and county extension offices. Persons were eligible to participate in the study if at least 18 years of age and engaged at their community gardening site in metropolitan Atlanta counties for at least 3 months. Gardeners who met the study eligibility criteria were invited to participate in focus groups near their community garden location. The focus groups were administered in private rooms in Atlanta libraries and county extension offices. Before participating in the focus groups and follow up demographic survey, study participants signed written informed consent forms.

A semi-structured focus group guide based on the TPB elicitation study framework (Francis et al., 2004) was developed to guide the discussions. The focus group guide began with questions about community garden benefits, soil contaminant concerns, and soil testing; these findings are reported elsewhere (Hunter, et al., submitted). Next, the guide centered on the advantages and disadvantages; supporters and non-supporters; and barriers and facilitators of composting, hygiene habitats, and mulching in community gardens. Behavioral beliefs were assessed [Hunter, et al., in review] by questions such as: *What do you think are the advantages of adding compost amendments to the soil during the next growing season? What do you believe are the disadvantages of adding compost amendments to the soil during the next growing season?* Normative beliefs were evaluated through the following questions: *What people or groups would expect you to add compost amendments to the soil? What groups would discourage composting?* Control beliefs were measured through questions such as: *What factors or circumstances would make it easier for gardeners to add compost amendments to the soil? What makes it difficult for gardeners to add compost amendments to the soil?*

Each focus group ran 75-90 minutes, was audio-recorded, and transcribed verbatim. As an incentive for participation, all focus groups participants were offered a free heavy metal soil test (valued at $35), as well a gardening gift bag that consisted of seeds, gloves, trowels, and factsheets on reducing soil contamination exposure in urban community gardens. The study protocol and forms were reviewed and determined exempt by Emory University Institutional Review Board.

Based on the research questions and review of focus group transcripts for emergent discussion topics, the primary author (C.H.) developed a codebook to outline and define specific themes (codes). The primary author and another analyst individually examined and coded the transcripts. After reviewing the codes independently, the analysts met to discuss, review and resolve code discrepancies. This process was conducted by reviewing each manuscript, comparing codes, and explaining rationale for each coded section (Hennink et al., 2010; Patton, 2015). After comparing and reconciling conflicting codes, the analysts developed a revised codebook (Appendix A). Using the revised codebook, the analysts recoded the transcripts, and the final coded themes were entered into NViVo 10 (QSR International Pty Ltd, Melbourne, Australia) software. Study team members reviewed NVivo summary reports by Node output and developed matrices to identify primary themes. These matrices were organized to understand frequency of mentions, to assess consistency of themes across focus groups, and to characterize TPB patterns (Patton, 2015). Specific TPB themes were organized by each of the three primary behaviors (i.e., composting, hygiene behaviors, and mulching) investigated in the study. Quotes that represent the strongest themes as defined by highest frequency of mentions are included in the results section.

Results

Characteristics of study participants and their community gardens

The study sample was 77% female, 69% non-Hispanic white, 26% non-Hispanic black, and 40% between the ages of 36-55 (Table 1). Four fifths of the study population had attained college degree, and 57% of the participants had an annual household income of at least $50,000. Most of the focus group participants were community garden leaders (80%) who had previously participated in garden training (79%). Community garden leaders are typically responsible for garden management including coordination of volunteers/members, communication, site maintenance, and educational workshops. More than half of participants identified their community gardens as neighborhood gardens (58%), and sixty-percent of participants' gardens had at least 30 garden members (60%) (Table 2). Slightly fewer than half of the community gardeners in the sample were working on gardens sited on land owned by their organizations, and most gardens were sited on at least 0.25 acres of land.

Composting

Advantages and Disadvantages

Participants shared some common beliefs reflective all three of the safe gardening practices (Table 3). However, most of these beliefs were specific to the safe gardening behavior. During the discussion about compost, participants most frequently mentioned the benefit of compost to improve soil quality. More specifically, participants expressed that compost can help to dilute harmful bacteria and fungi (e.g., downy mildew), neutralize pH, and improve soil texture and water retention. Several participants emphasized that compost breaks up soil and allows nutrients to be better absorbed by plants, thereby creating healthier, more nutrient-dense food. Example quotes from participants regarding advantages of compost are repeated below:

"It creates a high nutrient content in the soil. You know what you're putting in. It increases the level of earthworms that are doing their job and, it just makes the soil very dense and very beautiful…it's pretty fascinating to just watch things just kind of decompose, and I think it adds another level of health to the soil"

"Because if you ever put it[compost] down, if you ever look underneath it later on and see what it's doing to that clay soil, it starts breaking it up, and if you mix that clay in with it, it makes a really nice combination. Georgia clay sometimes has a bad reputation, but if you break it up and get it in there with that compost- They really help each other"

Other advantages discussed were that compost serves as a good waste reduction mechanism, promotes environmental stewardship, saves money for fertilizer, and provides a teaching opportunity for students to reduce waste and promote sustainability principles.

The most commonly perceived disadvantages of compost related to the challenges of identifying and monitoring source materials. Additional challenges were contamination from chemical spraying (intentional and unintentional runoff); availability of source materials (e.g., attaining enough green material, kitchen peels); and potential diseases in source materials. Participants shared that lack of education and motivation on composting properly could result in bad odors, rodents, and wildlife at or near the composting area.

"*Sometimes if people don't do it correctly, some folks have problems with rodents and things like that, so I guess neighbors could become upset if you had a compost bin and it attracted wildlife."*

"Sometimes it's hard to know the source of your materials…it could be full of weed seeds. That could be a challenge. I've read some pretty gnarly articles about cardboard, like not really knowing the source of that cardboard."

Moreover, participants mentioned the extensive amount of time, energy, and labor to create, monitor, and maintain compost piles was also a deterrent to composting. Also, participants discussed the varied quality of imported compost (donated and purchased) and the feasibility of composting based on the scale of the garden.

"I think the problem with most community gardens is composting isn't done at a large enough scale that it's practical. I mean, we have a demonstration area. We've got like five beds. When you consider the labor requirements to really do it right, it's a challenge."

Supporters and Non-Supporters

Supporters of compost included businesses (e.g., Terra Nova Compost, restaurants, tree companies), garden leaders, Master gardeners, gardening experts, non-profit organizations (e.g., Captain Planet Foundation, Trees Atlanta, Trees Georgia, Foodwell Alliance, Metro Atlanta Urban Farmers, Georgia Organics), County Extension Services, Arborists, as well as local and federal agencies (e.g., Centers for Disease Control and Prevention, US Department of Agriculture). Restaurants and neighbors concerned about odors and property values were mentioned as potential non-supporters. One participant noted that restaurants can be supporters or non-supporters depending on their motivations and willingness to input additional resources into sorting scraps:

"Restaurants can be a great resource, but sometimes they're hard to work with because you only want certain things, and then maybe they don't want to add anything extra to their routine."

Facilitators and Barriers

Facilitators of composting were resources (e.g. bins, space, materials, and instructions about composting) and increased awareness of compost availability by having compost pick up and drop off services or donated compost. Additionally, hosting free composting workshops and increasing the accessibility of source material (through restaurants and/or requesting leaves from neighbors and companies) were mentioned as excellent facilitators. To increase compost accessibility on site, one gardener suggested that it should be required labor of gardeners to compost:

"If there was more required labor expected out of each member of the garden, and you had three or four people that were going to come out every weekend, somebody who was going to supervise them and get the job done, it [composting] could be done, because people certainly do it in their own yards, and there's ownership in your own yard, so you know what you're doing and you've bought into that method, but it takes oversight and follow through."

Likewise, barriers of utilizing compost in community gardens included time and labor of turning the compost; maintaining a steady supply of green material and other source materials; lack of awareness on how to compost; potential for feedstock contamination; not knowing what's in donated/bought/created compost; and composting at large enough scale that's practical. A common barrier was difficulty of recruiting gardeners to participate in composting educational workshops due to other competing priorities. One participant shared:

"*They have a program on composting and how important it is to the soil, and why you need to chop it up so that it will decompose within a reasonable amount of time. The hardest thing about doing these classes is getting people to attend."*

Hygiene Behaviors

Advantages and Disadvantages

Participants shared that hygiene behaviors (e.g. handwashing, removing gardening shoes prior to entering the home, wearing gloves) had advantages such as reducing dirt and dust in the home, lessening housework and cleaning, minimizing the introduction of diseases (such as Mosaic Virus/Tobacco Disease) into the garden, and decreasing the transport of diseases from one plant to another. A consistent disadvantage to implementing hygiene habits was concern regarding exposure to healthy organisms/microbes in the soil (particularly for children).

"I'll rinse dirt off my hands, and beyond that, maybe I'm a slob or something, not very hygienic, but I figure to some degree healthy soil is healthy for people too--the microbes and all that stuff"

"But again, then are you going to eat off those hands? (laughs)…It's levels of how serious you want to get about this, and I tend to think that we've gotten into a very sanitized living where we don't want the least little bit of dirt, and I think sometimes people have more allergies and things like that because our bodies have stopped building up that immunity."

Other challenges mentioned were that disposable gloves and wipes generated additional waste. Some participants cited that gloves made gardening more difficult particularly if not correctly sized. There were also concerns about "where the soapy water was going" after washing hands and equipment.

Supporters and Non-supporters

Supporters of hygiene habits included teachers and some garden leaders. Teachers and some garden leaders were also mentioned as potential non-supporters along with parents/volunteer leaders. There was a sentiment that children should be exposed to more physical activity, outdoor work, and soil.

"The teacher at one of our schools wanted them to get dirty, because they're affluent children and they don't get dirty very much apparently."

"I'm notorious. I like to get my hands dirty, so I want the kids playing in the dirt. I want them to feel it, smush it, because after a while they start playing anyway, so I'm not a huge stickler for hygiene in the garden."

Facilitators and Barriers

Participants expressed that availability of materials (e.g., gloves, hand sanitizer, handwashing station; tippy tap, hand wipes, first aid kits) at the garden site or asking gardeners to bring these materials would make it easier for them to implement various sanitation behaviors. Additionally, gardeners expressed that having training and education on the importance of these behaviors would facilitate more compliance. A few gardeners mentioned that having a gardening agreement or physical signs around the garden to emphasize certain behaviors such as banning pets and pesticides could emphasize the importance of these hygiene behaviors. One participant shared, "*I also think like just education around foodborne illnesses and proper signage too, just making it easy, like mentally easy enough for everyone to see -- You know, because I'll forget to wash my hands or something like that, but if there's a sign constantly reminding you or something like that then it takes less mental energy and it's more likely to get done."*

Barriers to implementing hygiene behaviors included not having access or funding for on-site potable water and costs of resources such as gloves and first aid kits. A participant stated,

"We harvest spring water…we also are near a community center, so we have access to [potable] water. But other places that I know of may not have access to running water on the site."

Several gardeners also mentioned that these behaviors were very specific to each gardener and that it was difficult to control individual gardener behavior. One gardener shared that a barrier was gardeners' lack of awareness about foodborne illnesses and transmission, *"We're very concerned about people who harvest for the food pantry to realize that it's food, and there are things that you don't do to food. We really are advocating that and educating the community on those principles, because 85% of the foodborne illnesses come from vegetables. We tell people, look, if you're sick, don't harvest."*

Mulching

Advantages and Disadvantages

Key advantages of mulching included suppression of weeds, reduction of leaves/waste in landfill dumps, control of soil temperature and moisture, and decomposition of the mulch to create fertilizer. Gardeners also mentioned that mulching was an inexpensive method to beautify the garden while conserving water. Disadvantages of mulching were the potential for different types of diseases and pests added to the garden depending on the source material, mold (if too much moisture retained), and time and work to reapply mulch throughout the year. A participant shared "*But one of the bad things, because I did have a lot of tree cover, is it[mulch] did harbor mosquitoes because it retains water."* One gardener also mentioned "*Mulching and leaving it on through the winter makes it harder to start seedlings the following spring because of slugs and pill bugs and stuff."*

Supporters and Non-Supporters

Tree and maintenance companies and community garden leaders were mentioned as supporters of mulching; however, no non-supporters of mulching were identified in the focus groups.

Facilitators and Barriers

A facilitator of mulching is that it was viewed as readily available from multiple sources. Participants shared that some companies will drop off the mulch at the gardening site, which improves accessibility and reduces transportation time. Barriers to mulching included the time and labor to apply the mulch and uncertainty about the mulch source material: *"We're a little wary about the wood chips we get from tree companies, because you don't know if those trees were sprayed or not."* Other participants added that barriers to mulch included harboring pests and promoting fungi growth: *"We discovered that because of the termites that come out later, or the mushrooms… we're not allowed to have it[mulch] close to the building."*

Discussion

This qualitative study examined the behavioral, normative, and control beliefs of Atlanta community garden leaders about composting, hygiene behaviors, and mulching. Although these gardening practices are often recommended by government agencies, universities, and non-profit organizations to reduce potential soil contaminants exposures among gardens, few studies have utilized a theory-based framework to examine the underlying beliefs that shape why the recommended safe gardening behaviors may or may not be adopted. By investigating gardeners' salient beliefs, this study fills research gaps that can be applied to the development of interventions that promote safe gardening and to the design of quantitative studies that investigate gardeners' behaviors.

Exploration of the behavioral beliefs of gardeners in this study revealed that heathy soil was perceived as a key advantage to composting and mulching. Other studies have confirmed that compost and mulching contribute to improved soil quality in community gardens, but application of these practices may depend on social demographic factors (Egerer et al., 2018). Participants' behavioral beliefs related to hygiene centered around the benefits of minimizing the spread of dirt in homes. The themes identified in this study also illuminated barriers and facilitators to implementing safe gardening practices among urban community gardeners. Comparable to other studies, community garden leaders in this study discussed two major control beliefs that challenged implementation of all three behaviors: resources (e.g., funding, potable water, volunteers, compost source material), and training (Drake & Lawson, 2015; Harms, 2011; Henson et al., 2017). Control beliefs also included concerns about contamination of materials used for compost and mulch, as well as availability of water for handwashing. A key finding was that compost and mulch were perceived as practices that could introduce soil impurities such as pesticides and weeds; therefore, these practices were not viewed as mechanism to reduce exposure to chemical contaminants. While handwashing was discussed as a practice to reduce transfer of bacteria and diseases, it was not directly discussed in the context of chemical soil contaminants. Participants identified potential supporters and non-supporters (normative beliefs) that could influence gardeners' opinions regarding these behaviors. Community garden leaders were cited as supporters of all three behaviors. However, since most focus group participants were community garden leaders, more research should be conducted to understand whether garden participants are motivated to conduct behaviors supported by their garden leaders.

Study participants shared that improvement of soil quality to grow nutritious food was a key stimulus for compost production and utilization. Participants also discussed other compost advantages such as promotion of sustainability and advancement of children's environmental education. Similar to another study, participants desired more educational resources and instruction regarding how to compost to improve soil quality (M. L. Kaiser et al., 2015a). Participants expressed concerns regarding the feasibility of producing compost onsite or acquiring compost through purchases or donations. As highlighted in other compost related reports (Ahead, 2015; Foodwell Alliance, 2017), common challenges identified were accessibility, affordability, and sustainability of obtaining quality, uncontaminated compost and compost source materials. To generate and use compost properly and consistently, participants shared that sufficient training, time, labor, resources, and land were key facilitators.

Participants discussed multiple advantages of executing different hygiene behaviors related to gardening. Although participants expressed the importance of handwashing, produce washing, and removing shoes to reduce spread of potential diseases, several participants shared that these behaviors could also minimize exposure to good microbes. This sentiment was frequently mentioned in discussion of children's access to the garden and exposure to dirt. Similar to other handwashing behavioral studies, reducing barriers to handwashing were viewed as strongly influencing handwashing intention (J. M. Soon & R. N. Baines, 2012; York et al., 2009). To promote hand hygiene at the community garden site, study participants expressed that access to potable water, handwashing stations, and other resources (e.g., gloves, first aid kit, handwashing signs at the garden) would be beneficial. Moreover, gardening training and educational materials that follow evidence-based risk communication best practices such as clear language, graphics, risk perception and narratives (Jacob, Mathiasen, & Powell, 2010) may also help encourage healthy garden hygiene behaviors.

Focus group participants shared several favorable opinions about mulching related to availability, soil quality, water conservation, and garden aesthetics. However, gardeners did not mention the importance of mulching in reducing windblown soil contaminants. Primary challenges discussed were related to contamination of mulch source material, which could result in harmful chemicals and pests in the garden soil. Other mulch-related challenges included excessive soil moisture and lack of labor resources for mulch application and maintenance. To combat these barriers, advocates of mulching that participants identified in this study, as well as volunteer organizations could assist with mulch testing, application, and training.

This study has several limitations. First, while the researchers strived to recruit diverse perspectives of gardeners from different community garden settings (e.g., neighborhood, schools, faith-based communities, and parks), the focus group participants may not reflect the broader population of Atlanta community gardeners. Demographic factors such as race, income, and garden location may be associated with gardeners' perspectives on soil management and safe practices (Egerer et al., 2018; Henson et al., 2017; Wong et al., 2017). Therefore, the study findings may fail to appropriately characterize the varied perspectives and experiences that influence adoption of the practices among gardeners in Atlanta. Second, time constraints limited the depth of the discussion regarding some behaviors. For example, hygiene behaviors encompass multiple actions including handwashing, glove wearing, produce washing, and leaving gardening materials outside of the home. Each of these behaviors could comprise the emphasis of an entire focus group with each behavior discussed individually. Third, the TPB framework guided the discussion toward individual beliefs; therefore, social ecological factors (e.g., city polices related to urban agriculture, social networks, community empowerment) that could influence gardening practices were not explicitly explored in the focus group discussion. Given the collective nature of community gardens, exploration beyond the individual-level beliefs to the interaction of community, environmental, and policy elements may be important areas for research (Okvat & Zautra, 2011). Although participant interaction during focus groups can enrichen the discussion, a limitation of the focus group method is that participants may have provided responses that were perceived as socially acceptable by other participants (Podsakoff, MacKenzie, & Podsakoff, 2012). To combat this social desirability bias, observations related to these practices at the garden may be informative instead of relying on solely on self-reporting through focus groups or surveys.

Similar to other cities, current land use activities and site history can contribute to increased levels of harmful chemicals in Atlanta soils (Deocampo, Reed, & Kalenuik, 2012) that could present a risk to community gardeners. For example, five of the eight vacant lots chosen for the Aglanta "Grows-

A-Lot" program had a least one soil toxicant that was above the cautionary limit, warranting the use of safe gardening practices (Groundwork Atlanta, 2018). Atlanta community gardens contribute not only to strengthening local food efforts, but also providing educational, cultural, youth, and senior programs (Alliance, 2017; Foodwell Alliance, 2016). Since community gardens constitute key components of several educational (Aftandilian & Dart, 2013; Doyle & Krasny, 2003), public health (Centers for Disease Control and Prevention, 2015; D. Smith et al., 2013), and urban planning (Goldstein, Bellis, Morse, Myers, & Ura, 2011a; Horst et al., 2017) strategies, it is likely that diverse populations will be in contact with community garden soils. Therefore, these study findings have implications for stakeholders that engage community gardeners in multiple contexts. Application of these study findings to educational programs, policies, and other initiatives can support the sustainability and safety and of urban agriculture in other cities.

Conclusion

The TPB provided this study a logical framework to explore the underlying beliefs and motivations about safe gardening practices. Gardeners expressed multiple benefits of conducting these practices; however, they are not thinking of these practices in the context of reducing exposure to soil contaminants. Therefore, safe gardening interventions should consider both the perceived benefits and barriers of these practices, as well as improve awareness regarding mitigation of soil contaminants as an additional advantage. Examples of remaining knowledge gaps include 1) Will interventions that incorporate these study-identified beliefs result in sustainable change related to gardeners’ behavior? 2) How do community garden setting (e.g., neighborhood, school, park), gardener sociodemographic characteristics, and other external factors interact to influence whether these practices are implemented? Future research could build upon the TPB behavioral, normative, and control beliefs explored in this study to quantitatively investigate how attitudes, subjective norms, and perceived behavioral control are associated with intention to conduct these safe gardening behaviors. Case studies should examine strategies of stakeholders such as community members, universities, food policy councils, urban planners, and government leaders that have successfully utilized their resources to promote these safe gardening behaviors in different community garden settings. From a socioecological perspective, individual, community, and policy level approaches are needed to comprehensively protect vulnerable populations from potential soil contaminant exposures in community gardens.

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Declaration of interest statement

The authors have no conflicts of interest to declare.

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Table 3.1: Focus Group Participant Demographics

Garden Role	**N (%)**
Community Garden Leader	21 (80.8)
Gardener/ Garden plot owner	1 (0.04)
Volunteer	3 (0.12)
Other	1 (0.04)
Garden Training	
No	5 (20.8)
Yes	19 (79.2)
Type of Garden training	
No (have not participated in training)	2 (9.1)
Nonprofit Gardener Training	8 (36.4)
Master Gardener Training	10 (45.5)
Other	6 (27.3)
Age	
18-35	4 (16.0)
36-55	10 (40.0)
56-65	5 (20.0)
66-75	6 (24.0)
Gender	
Female	20 (76.9)
Male	6 (23.1)
Ethnicity	
Hispanic/Latino	3 (11.5)
Not Hispanic/Latino	23 (88.5)
Race	
American Indian or Alaska Native	0(0.0)
Asian	0(0.0)
Black or African American	7(26.9)
Native Hawaiian or Other Pacific Islander	0(0.0)
White	18 (69.2)
Other (Bi-racial)	1 (3.9)
Highest Level of Education	
High School Graduate or less	0 (0.0)
Vocational/Technical School	1 (4.0)
Some College	2 (8.0)
University/College Graduate	14 (56.0)
Graduate School or Higher	8 (32.0)
Annual Household Income	
Less than $24,999	4 (17.4)
$25,000 to $49,999	6 (26.1)
$50,000 to $99,999	7 (30.4)
$100,000 or more	6 (26.1)

Table 3.2: Focus Group Participants' Community Garden Information

Garden Type	**N(%)**
Neighborhood	15(57.7)
Park	6 (23.1)
School	2(.08)
Faith-based	1(.04)
Senior Center	1(.04)
Other	1(.04)
Land Ownership Status	
Owned	10(40.0)
Leased	2 (8.0)
Community Land Trust	1(4.0)
Municipal Agreement	5(20.0)
Other	7(28.0)
Estimated Garden Size	
Less than .25 acre	6(24.0)
.25 acres-.49 acres	6(24.0)
.5 acres-1 acre	11(44.0)
Greater than 1 acre	2(8.0)

Table 3.3: Summary of Participants' Beliefs of the Safe Gardening Practices

Belief Type	Primary Themes	
Behavioral Beliefs	Advantages	Disadvantages
	• Improve soil quality • Minimize waste • Create nutrient-rich food • Increase exposure to healthy bacteria • Promote sustainability	• Introduce disease and pests (mulching and compost only) • Generate waste (e.g. disposal gloves, wipes) • Reduce garden yield if improperly implemented
Normative Beliefs	Supporters	Non-Supporters
	• Community Garden Leaders • Master gardeners and other gardening experts • Cooperative Extension Office • Non-profit organizations • Businesses (e.g., restaurants, tree maintenance companies) • Local and federal government agencies	• Community Garden Leaders • Neighbors • Businesses
Control Beliefs	Facilitators	Barriers
	• Financial resources • Human capital (volunteers) • Training • Gardener participant Agreements • Access (e.g. potable water, mulch and compost source materials) • Garden signage and tools (e.g handwashing stations, compost bins)	• Time and labor requirements • Contamination of source materials • Scale practicality • Lack of control over individual gardener behavior • Lack of awareness of behaviors and potential consequences

Chapter 4: Applying the Theory of Planned Behavior to Investigate Heavy Metal Soil Testing and Handwashing Intention Among Community Gardeners in the United States

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Abstract

Community gardens are beneficial in many ways, but heavy metal soil contaminants such as lead and cadmium pose health risks and can threaten the viability of community gardens in urban environments. Preventative behaviors such as soil testing can help to mitigate these risks, and hand washing after garden activities may reduce soil exposure on hands and produce. This study examined heavy metal soil testing and handwashing intention among U.S. community gardeners using the Theory of Planned Behavior (TPB). An elicitation phase revealed salient beliefs among community gardeners and informed the development of an online cross-sectional questionnaire. This online questionnaire was administered to American Community Gardening Association Conference attendees and gardener affiliates (N=500) from July to August 2017. Study findings indicate that 82% of the gardeners were willing to test their soil for heavy metals and 74% intended to wash their hands after working in their garden plot. Logistic regression revealed that the TPB constructs— attitudes, subjective norms, and perceived behavioral control —were all statistically significant predictors of soil testing intention and handwashing behavior. The odds of soil testing intention increased with attitude (aOR =4.13, 95% CI: 2.31, 7.36), subjective norms (aOR=3.02 95% CI: 1.82, 5.01), and perceived behavioral control (aOR=1.86, 95% CI: 1.09, 3.15). The odds of handwashing intention increased with attitudes (aOR= 3.09, 95% CI: 1.30, 7.33), subjective norms (aOR=4.58, 95% CI= 2.27, 9.25), and perceived behavioral control (aOR=2.92 95% CI: 1.23, 6.96). Participants' education level and chemical practice methods (e.g., pesticide use, USDA organic) were also associated with intentions. Study findings have implications for interventions involving safe practices for community gardens.

Keywords: Soil contaminants; urban agriculture; Theory of Planned Behavior; environmental psychology

Introduction

Community gardens are growing in popularity and are associated with an array of positive outcomes (Al-Delaimy & Webb, 2017; National Gardening Association, 2014; Palmer, 2018). The American Community Gardening Association estimates that there are over 18,000 community gardens in at least 250 towns in the United States and Canada (American Community Gardening Association, 2018). Practitioners and academics from public health, urban planning, education, environmental management, and sustainability sectors investigate and promote community garden benefits (Horst et al., 2017; Santo, 2016). For example, the Centers for Disease Control and Prevention recommends community gardens as a strategic priority to improve fruit and vegetable consumption (Centers for Disease Control Prevention, 2011), and the American Planning Association advocates for the utility of community gardens in food systems planning (American Planning Association, 2007).

Due to natural processes and anthropogenic sources of pollution in urban environments, however, heavy metals and metalloids such as lead, arsenic, and cadmium, may be present in urban community garden soils (Latimer, Van Halen, LA, Weaver, & Foxx, 2016; Mitchell et al., 2014a; Witzling et al., 2010). Past and current activities near the garden site including heavily-trafficked roadways, industrial activities, manufacturing, landfill waste, pesticide application, waste burial, lead paint and gasoline, and agricultural runoff are contributors to heavy metal contamination in urban soils (Ajmone-Marsan & Biasioli, 2010; B. J. Alloway, 2012). Bioavailability is the percentage of a contaminant in soil that is available for absorption across biological membranes into organisms (Drexler et al., 2003; Hettiarachchi & Pierzynski, 2004), and is an important aspect to consider for health outcomes. The concentration of soil contaminants that are bioavailable to plants and humans depends on soil properties such as pH, solubility, mineralogy, soil texture, concentration of other contaminants and amendments, and organic matter (Elless, Bray, & Blaylock, 2007; Khan et al., 2015; Wilson et al., 2014).

Soil testing is a first step toward quantifying these soil properties that can guide subsequent gardening practices. For example, soil contaminant testing results can be used to inform remediation efforts, optimize plant growth, improve soil fertility, and advance garden sustainability in urban environments. Although some private and federal laboratories and extension offices at land-grant universities have soil contaminant testing capabilities, gardeners may not test their soil or only test their soil for common measures such as pH, phosphorus, and organic matter content.

Wearing gloves as well as washing hands and garden produce with soap and water are recommended practices to reduce ingestion of soil particles, which is a common route of exposure. If handwashing is not feasible, gloves and hand sanitizer are also safe practices to minimize soil exposure (Ashley Chaifetz et al., 2015). Handwashing is more commonly discussed in the context of pathogens that can cause foodborne illnesses resulting from inadequate water sanitation and hygiene (WASH) as well as noncompliance to good agricultural practices (GAPs), which are guidelines for produce handling, harvesting, and storage. Although hand-hygiene studies have been conducted in the hospital (Erasmus et al., 2015), among food workers (Green et al., 2007; Medeiros, Cavalli, Salay, & Proença, 2011) and farm workers (de Aceituno et al., 2015), as well as in other settings, very few studies have focused on gardener handwashing behaviors. In community and school garden settings, handwashing enforcement may be challenging due to: 1) increased frequency of hand to mouth behavior among children combined with difficulties in monitoring behavior in settings with large child to supervisor ratios; 2) lack of access to handwashing tools; and 3) individual gardener preference.

Only a few studies have examined soil contamination testing, hand hygiene, and other practices to reduce soil toxicant exposures among community gardeners in the United States. These studies have documented that challenges to soil testing include cost, sampling uncertainty, contaminant spatial variability, interpretation of results, and lack of clear guidelines/screening levels for some metals (B. F. Kim et al., 2014; Schwarz et al., 2016). The few studies of hygiene behavior in gardens have shown lack of access to resources (e.g., water, handwashing stations, hand sanitizer and other materials). In addition, poor food safety knowledge can influence handwashing behaviors (Ashley Chaifetz et al., 2015; Guo et al., 2018). These studies, furthermore, are typically concentrated in one geographic setting, use qualitative approaches, have small sample sizes and/or are not theory-bound (M. L. Kaiser, Williams, Basta, Hand, & Huber, 2015b; B. F. Kim et al., 2014; Witzling et al., 2010). While not focused on gardens per se, several studies of farmers have demonstrated that attitude and perceived behavioral control, which are constructs from the Theory of Planned Behavior, can affect their adoption of practices related to food safety, soil management, and other sustainable agricultural practices (Adusumilli & Wang, 2018; Baumgart-Getz, Prokopy, & Floress, 2012; Parker, Wilson, LeJeune, & Doohan, 2012; Ritter et al., 2017; Zeweld, Van Huylenbroeck, Tesfay, & Speelman, 2017) . Studies of farm workers have indicated that perceived control and availability of facilities are associated with hand hygiene practices (Bartz, Sunshine Lickness, et al., 2017; J. Soon & R. Baines, 2012). However, data are limited on whether these findings can be applied to urban community gardeners, who have different motivations and resources than commercial farmers or farmworkers.

The Theory of Planned Behavior (TPB) provides a well-established conceptual framework for understanding behaviors and designing behavioral interventions (Steinmetz, Knappstein, Ajzen, Schmidt, & Kabst, 2016). According to TPB, attitude towards a behavior, subjective norms, and perceived behavioral control are the primary influencers of behavioral intention, which is an antecedent to behavior (I Ajzen, 2002; Montano & Kasprzyk, 2015). Attitude toward the behavior is the extent to which the behavior is favorably or unfavorably valued. Subjective norms are perceived social pressures to perform or not perform a behavior. Perceived behavioral control (PBC) is perceived ability of conducting a behavior, which is influenced by the presence of conditions that make a behavior easy or difficult to perform. The theory hypothesizes that the stronger PBC and higher favorability of attitudes and subjective norms toward a behavior, the stronger the behavioral intention. Numerous TPB-related studies have indicated that behavioral intentions are good predictors of behavior, particularly when the behavior is under volitional control, a behavior that a person can willfully decide whether to implement or not to implement (Icek Ajzen & Fishbein, 2005).

Using TPB as a theoretical framework, the aim of this study is to investigate factors that may contribute to soil testing and handwashing intention among community gardeners. Demographic and sociocultural variables are often considered a background factors in TPB that may also impact beliefs, attitudes, and perceived behavioral control towards a behavior. Therefore, this study also examined gardener demographics as well as garden contextual variables such as garden region location, garden site history, garden chemical practices, and proximity to older housing stock and roadways (Säumel et al., 2012) that may impact soil contaminant concentrations and exposure. Garden locations and contexts may influence soil testing and other mitigation behaviors, since some cities (e.g., New York, Chicago and Boston) may require garden soil testing and have industrial histories that could contribute to greater soil contamination.

Methods

Study Design, Population & Recruitment

This study utilized a cross-sectional, online questionnaire that was open to potential respondents from August to September 2017. The study population was community gardeners and leaders who were at least 18 years old. Participants were initially recruited in person at a recruitment booth during the 2017 American Community Gardening Association Conference (ACGA) in Hartford, CT. Study participants were asked to complete the online questionnaire on an electronic tablet. Hardcopies of the questionnaire were available at the recruitment booth. The research questionnaire link was also shared on the ACGA Facebook page and was subsequently re-shared on Facebook by community garden groups affiliated with ACGA. Community gardeners received an electronic $10 Amazon gift card as an incentive for participating in the questionnaire.

Elicitation Phase and Questionnaire Development

Questionnaire items were derived from an elicitation phase involving five focus groups (n=26) with Atlanta community garden leaders in February to March 2017 (Hunter, et al., under review). Participants described salient beliefs related to advantages/disadvantages of soil testing to inform attitude and behavioral beliefs; advocates and opponents of soil testing to inform normative beliefs and subjective norms; barriers and facilitators to soil testing to inform control beliefs and PBC. The strongest behavioral, normative, and control beliefs were used to develop the questionnaire items. Initial questionnaire items were piloted among gardeners that were recruited via email from community garden leaders in the Atlanta area and then interviewed to solicit feedback regarding questionnaire length, wording, question sequence, incentives, and overall online usability. Based on the pilot questionnaire respondents' recommendations, the questionnaire was modified and retested among pilot respondents to create the final questionnaire.

Measures and Description of Questionnaire Questions

The questionnaire included ten sections: knowledge and risk perception of soil contaminants, past gardening behaviors, beliefs related to heavy metal soil testing, heavy metal soil testing subjective norms, heavy metal soil testing barriers and facilitators, heavy metal soil testing intention, handwashing practices, compost practices, community garden information, and demographic information. All TPB questionnaire items were measured using a 5-point Likert Scale with the anchors differing based on the primary TPB construct. Each TPB construct was created as the average of the items according to TPB guidelines (I Ajzen, 1991; Francis et al., 2004). <u>Attitudes</u> toward soil testing and handwashing (A) were calculated as the average of three-items as indicated in Table 2, with response options ranging from 1 (unimportant) to 5 (important). <u>Subjective Norms</u> (SN) were calculated as the average of a three-items with ratings ranging from 1 (strongly disagree) to 5 (strongly agree). For example, participants were asked to rank "I feel social pressure to conduct heavy metal soil testing in my community garden plot."

Perceived Behavioral Control (PBC) was calculated as the average by item measures. For example, participants ranked "Washing my hands after working my community garden plot" is 1 (not under my control) to 5 (under my control), served as a questionnaire item to assess PBC.

To assess Intention to test their soil or wash their hands, participants were asked to rate three statements such as "I expect to conduct heavy metal soil testing at my garden plot during the next growing season" from (1) strongly disagree to (5) strongly agree. These items were averaged to create an Intention score. Intention scores in the study were highly skewed with over 70% and 80% of participants indicating that they either agreed or strongly agreed and that they were likely to conduct soil testing and handwashing, respectively. Since logarithm and other types of transformations did not improve the overall distribution of the intention variables, these variables were dichotomized where responses of 1 to less than 3.5 were coded as "Low Intention", and responses greater than 3.5 were coded as "High Intention" (MacCallum, Zhang, Preacher, & Rucker, 2002).

Statistical Analysis

All data were imported into Statistics and Data Analysis (Stata 15.0, StataCorp LP, College Station, TX) software, cleaned, and coded appropriately (e.g., reverse coded, dummy variables where applicable). TPB variables were screened for missing data, normality, collinearity, and correlations among variables. Descriptive statistics, including means, standard deviations, and correlations were calculated and examined for questionnaire items underlying each TPB construct. Since questionnaire items are novel and have not been previously reported in this study population, Cronbach's alpha was calculated to assess internal consistency among TPB items. Frequencies were used to examine distributions. Chi-square tests were used to determine if the intention of each behavior was significantly associated with demographic variables. Logistic regression with robust standard errors to account for potential social connections among gardeners was used to predict soil testing and handwashing intention with TPB predictors (H. White, 1980). Demographic and garden contextual variables that were significantly associated with intention were included in the logistic regression analysis as covariables. These variables were screened for intervariable correlation prior to inclusion in the logistic regression. For all statistical tests, statistical significance was defined by p-values <0.05.

Of the 500 participants, 447 (89.4%) completed all the questionnaire items related to TPB constructs. Review of missing patterns data did not reveal that missing variables or items were attributed to certain IDs or variables; therefore, data were not imputed for missing values. After review of the distribution of the demographic variables, some variables were collapsed into two categories: Income- Less than $50,000 (Reference) and greater than or equal to $50,000; Education- Less than College (Reference) and Some college and above.

Results

Participant Demographics and Community Garden Characteristics

As shown in Table 1, half of the respondents were aged 36-55 years, with only 4.0% older than 66 years old. Seventy four percent of the questionnaire respondents were male. The majority of respondents were White (87%), followed by Black or African American (4.8%) and American Indian or Alaska Native (3.2%). Vocational/Technical School was the most common level of education (58%), followed by some college to completion of college (22.3%). Most respondents reported their household income to be $50,000 to $99,000 (74%). After dichotomizing income and education variables, most participants reported incomes greater than $50,000 (380, 83%) and less than college education (283, 60%).

The questionnaire data included responses representing community gardens from all 50 U.S. States. The states with the highest number of respondents were California (8.7%), Massachusetts (8.5%) and Washington (7.4%) (Figure 2). Most participants were affiliated with gardens in the South (30.49%) and the Northeast (27.5%) (Table 1). The most frequently reported types of community gardens were in park (34.6%), neighborhood (34.0%) and school settings (9.0%). Over half of the participants indicated that their community garden was located on at least 0.5 acres of land or more. Thirty-three percent of participants reported that their garden had been established for 1-5 years, but almost a third (31.3%) did not know how long the garden had been in existence. About half of participants reported garden site history as a park site, 10% as a vacant lot, 9.4% industrial site and 16.7% didn't know the site history. Only 11% of respondents reported that they used conventional methods (involving pesticides) in their community garden and over half of participants indicated that children are often present in the garden. In terms of potential hazards that could contribute to soil contamination, 6% and 49% of participants indicated that their gardens were in close proximity (less than 3 feet) to roadways and were unsure whether their garden was near pre-1978 housing, respectively.

Description of TPB Constructs

Study participants reported positive attitudes for soil testing (M= 3.95, SD=0.76) and handwashing behavior (M=4.10, SD=0.60) (Table 2). Mean scores for subjective norms were closer to neutral for soil testing behavior (M= 3.35, SD=0.96) and slightly higher for handwashing behavior (M=3.77, SD= 0.75). The average score for "I feel social pressure to conduct heavy metal soil testing in my community garden plot was 2.72, indicating relatively low perceived social pressure influence. The average PBC score for handwashing behavior (M=3.82, SD=0.68) was indicative of a moderately strong PBC. However, soil testing PBC items ranged from neutral to low, with the lowest scored item related to whether conducting heavy metal soil testing was up to the gardener (M=2.52, SD=1.01). Most participants exhibited strong intentions to conduct heavy metal soil testing and handwashing after gardening, with 73.8% exhibiting a high intention for soil testing and 80.4% exhibiting a high intention for handwashing. Positive correlations were observed among TPB variables for both soil testing and handwashing (Table 3). Additonally, the internal consistency of the TPB constructs for both behaviors were acceptable (Cronbach alpha > 0.6).

Logistic Regression

The adjusted logistic regression models explained 49% of the variance (Adjusted R^2 =0.49) of the intention to test soil and 50% of the variance (Adjusted R^2=0.50) of intention to wash hands (Table 4). TPB variables accounted for 34% and 37% of soil testing and handwashing intention respectively. Variables that were significantly associated with intention to test soil and wash hands, via chi-square analysis, were garden context, income, age, race, education, garden region, gardener chemical practice method and garden site history. These variables were therefore adjusted for in the logistic regression model. All TPB variables were statistically significant in the soil testing and handwashing logistic regression models. The odds of soil testing intention increased with a positive attitude (aOR=4.13, 95% CI: 2.31, 7.36), stronger subjective norms (aOR=3.02 95% CI: 1.82, 5.01), and higher PBC (aOR=1.86 , 95% CI: 1.09, 3.15). The odds of handwashing intention increased by three-fold with an increase in positive attitudes (aOR= 3.09, 95% CI: 1.30, 7.33) and perceived behavioral control (aOR=2.92 95% CI: 1.23, 6.96). Subjective norms had strongest influence on handwashing intention (aOR=4.58, 95% CI= 2.27, 9.25). Education and garden chemical practices also had a statistically significant influence on both behaviors. Gardeners with less than a college education were significantly more likely to have a higher intention to test their soil (OR=0.11, 95% CI: 0.05, 0.25) and wash their hands (OR=0.23, 95% CI: 0.08, 0.61). The odds of soil testing and handwashing intention decrease a factor of 0.20 and 0.10, respectively for gardeners that use pesticides compared to gardeners that use natural (without use of pesticides but not USDA certified organic) methods, holding other variables constant.

Discussion

To our knowledge, this is the first study to utilize the TPB to quantitatively measure factors that influence heavy metal soil testing and handwashing intentions among a large sample of community gardeners across the United States. The study findings illustrate that the TPB may serve as a relevant framework for examining community gardeners' decision to test their soil or wash their hands after gardening. Study results indicate that the intention to test soil and wash hands were significantly associated with attitude, subjective norms, and PBC. These variables accounted for 34% of the overall variance in soil testing and 37% handwashing intention in the unadjusted logistic regression models. These results are comparable to a metanalysis of TPB studies, which illustrated that the TPB variables account for an estimated 39% variance of intention across a range of behaviors (Armitage & Conner, 2001). Most of the study participants indicated that they intended to test their soil for heavy metals within the next growing season to sometime next year (73.8%) or wash their hands after gardening (80.4%). Given these strong behavioral intentions, investigation of factors that underlie intentions become more critical to facilitate transition from behavioral intention to action.

While participants ranked favorable attitudes and influential subjective norms towards soil testing, participants ranked PBC for soil testing neutral or low, indicating that gardeners may experience barriers related to heavy metal soil testing. This result supports the findings of site-specific research of community gardeners, which concluded that soil testing challenges were related to perceived behavioral control challenges such as paucity of training, financial support, and interpretation of results (Harms et al., 2013; M. L. Kaiser et al., 2015b; B. F. Kim et al., 2014; Witzling et al., 2010). Development of rapid, lower-cost soil testing tools (Minca, Basta, & Scheckel, 2013; Moller, Hartwell, Simon-Friedt, Wilson, & Wickliffe, 2018) and opportunities to make soil testing more widely available may influence some gardeners to test their soil. Similar to other studies of food safety and protective behaviors, targeting PBC, particularly related to self-efficacy in interventions may help to increase behavioral compliance (Kouabenan & Ngueutsa, 2016; Milton & Mullan, 2012; Mullan, Allom, Sainsbury, & Monds, 2016). Moreover, studies recommend that achieving high PBC to perform a behavior occurs when people: 1) believe they can perform the behavior; 2) possess the resources to conduct the behavior; and 3) are able to overcome or manage barriers to the behavior (I Ajzen, 2002; Yzer, 2012). Attitude was the strongest explanatory factor of soil testing intention, and beliefs underlying this construct, such as motivations for gardening and understanding soil quality could promote a positive attitude towards soil testing. Comparable to other studies, these findings suggest that framing the positive outcomes of soil testing may motivate gardeners more than a problem identification approach (Schwarz et al., 2016).

Effective handwashing is beneficial for not only reduction in soil chemical exposures, but also microbial exposures and risks in multiple settings. Studies of farm workers have documented that microbes can be transferred from hands to produce and vice versa; therefore, hand hygiene and produce washing interventions can reduce this transfer (Bartz, Lickness, et al., 2017; de Aceituno et al., 2015). Results from this study indicate that gardeners with more optimistic attitudes, more positive subjective norms, and higher PBC were more likely to have positive intentions to wash their hands. Interventions should consider enlisting perceived influencers to encourage these behaviors as well as promoting handwashing benefits and reducing barriers such as handwashing stations on site. Hand hygiene research in other settings have indicated that that this behavior can be challenging to adopt and sustain long-term. Therefore, best practices such as advancing hand hygiene attitudes, improving self-efficacy, and conducting multiple trainings over time have been recommended to increase sustainability of hand washing (Huis et al., 2012; Soon, Baines, & Seaman, 2012).

This study examined demographic factors and garden characteristics that may influence soil contaminant levels and intention to conduct the two behaviors. While income, geographic region, age, race, and garden site history were statistically insignificant covariables, education level and chemical practice methods were statistically significant covariables. Lower education was associated with higher soil testing and handwashing intention. It should be noted that most of the participants with less than college had vocational/technical school training. Given the horticultural or other agriculture specific training curriculum in vocational/technical schools, this type of educational training may contribute to why it is more likely for gardeners with this education to conduct protective behaviors than those with college-degrees not specific to horticultural training. Gardeners that use pesticides may be less likely to test their soil or wash their hands due to general lack of concern and low perceived risk of exposures. Previous studies have indicated that gardeners have varied perspectives and attitudes related to soil contaminant risks (Harms et al., 2013; B. F. Kim et al., 2014; Wong et al., 2017), which could potentially influence their decision to test their soil for contaminants and wash their hands.

Exposures to chemicals found in soil contaminants can have long term effects among children and other vulnerable populations even at low dose exposures (Izquierdo, De Miguel, Ortega, & Mingot, 2015; Weiss, 2000). The importance of modeling and enforcing safe gardening behaviors is underscored by 73% of questionnaire participants indicating that children either sometimes or frequently visit their community garden and nine percent of participants indicating that their garden was in a school context. Research has indicated the number of U.S. school-based gardens has increased over time, particularly among schools with a USDA Farm to School based program (Turner, Eliason, Sandoval, & Chaloupka, 2016). Since the Community Preventive Service Task Force as well as other international organizations recommend school gardening interventions to increase vegetable consumption among children (The Community Guide, 2018) (Yang et al., 2017), the number of school and early childhood education gardens may continue to increase. Moreover, school gardens have been implemented as an environmental equity tool in minority and low-income settings where industrial emissions and other environmental hazards may be more prevalent (Johnson, Ramsey-White, & Fuller, 2016; Ray, Fisher, & Fisher-Maltese, 2016). Incorporating soil testing and handwashing practices as well as other good agricultural and handling practices can reduce potential environmental hazards and liability concerns for school garden stakeholders (Turner et al., 2017; US Department of Agriculture, 2017).

There are several strengths of this study. By incorporating theory-based questionnaire items derived from focus group formative research, behavioral determinants of soil testing and handwashing could be explored and potentially targeted for behavioral intervention. In addition to the TPB variables, demographic variables were incorporated into the model to improve explained variance in soil testing intention. This study incorporated a relatively large and geographically diverse sample of community gardeners in the United States. Previous studies of community gardens are often city or region specific; therefore, challenges arise in comparing practices among different cities. Additionally, this study adds to the literature by inclusion of community gardens in different contexts (e.g. parks, schools, neighborhoods), chemical-practice methods, site histories, and garden proximity to roads and older housing. Garden contextual information can give rise to how specific chemical practices and garden siting policies could be better integrated into training to promote safe behaviors and awareness. About half of participants were unaware whether their garden was near older housing that may have lead paint, 16.6% were unaware of their garden's previous site use, and about 31% were unaware of how long their garden had been established. These contextual factors may influence concentrations of soil contaminants and may affect other gardening behaviors. For example, one study has suggested that more well-established gardens that implemented soil tilling over long period of time may have resulted in dilution of soil contaminants and lower soil contaminant concentrations (M. L. Kaiser et al., 2015b).

Despite these strengths, this study has several limitations that should be taken into consideration. First, the study utilized a cross-sectional design; therefore, the study was unable to access causality and whether soil testing and handwashing intentions and behaviors may change over time. Second, the study assessed behavioral intentions, but did not examine actual soil testing and handwashing behavior. While intention is typically a strong predictor of behavior, it is not a surrogate for actual behavioral execution. Third, the study examined injunctive norms (others' expectations) for subjective norm measurement as specified by TPB, but did not assess descriptive norms (others' behavior) which may also influence intention (Rivis & Sheeran, 2003). Additionally, most study participants were white males and may not be representative of the population of community gardeners in the United States. Convenience sampling, particularly through recruiting members of the ACGA and Facebook groups, presents a social connectivity among participants who may share similar gardening convictions that may not be reflective of community gardeners outside this social circle. However, convenience sampling is frequently used in studies where access and recruitment of a large sample size of the target population is challenging. Finally, individual behavior is multi-factorial, and constructs not explicitly included in the present study such as knowledge, trust, and risk perception, may interact with TPB variables to further explain behavioral intention (Gifford & Nilsson, 2014; Lobb, Mazzocchi, & Traill, 2007) (Ferrer & Klein, 2015).

Conclusion

This study adds a unique contribution by providing a theoretical framework to prioritize specific intervention targets that are predicted to influence soil testing and handwashing intention. Community gardeners in different contexts experience multiple, competing challenges that require time and resources (Burt, Luesse, Rakoff, Ventura, & Burgermaster, 2018; Drake & Lawson, 2015); therefore, interventions to address safe gardening practices need to be relevant and efficient. Public health interventions founded in theoretical frameworks have been shown to be more effective in modifying behavior than those not using theory (Glanz & Bishop, 2010).

Several studies have outlined challenges that gardeners may face when confronting soil contamination testing and sustainable practices for urban soil management (Wortman & Lovel, 2013); however, fewer studies have examined factors to improve behavioral interventions that address these challenges. The study results suggest that theory-based interventions targeted on improving attitude, subjective norms, and PBC may influence soil testing and handwashing intentions. Future studies could examine pre- and post-interventions focused on training and soil testing assistance. Community gardening training should not only be aimed at improving soil contaminant knowledge but should also address TPB variables such as attitudes and perceived behavioral control towards soil testing and handwashing (Huis et al., 2012; Pilling et al., 2008). It should be noted that TPB is individual behavioral model that does not directly address the complex, multi-level factors that affect community garden soil management. For example, land use policies and environmental justice concerns related to vacant lands provide context for potential soil pollutants and should be explored further in research related to community garden soil testing and best management practices (McClintock, 2012; Schwarz et al., 2016).

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Table 4.1 Demographic characteristics of the respondents and their community gardens

Demographic Variable		**n**	**Percent**
Gender	Female	124	26.4
	Male	345	73.6
Age	18-35	179	38.0
	36-55	236	50.1
	56-65	37	7.9
	66 or older	19	4.0
Income	Less than $24,999	30	6.3
	$25,000 to $49,999	45	9.6
	$50,000 to $99,999	348	73.9
	$100,000 or more	32	6.8
	Decline to state	16	3.4
Education	Less than High School to High school Graduate	10	2.1
	Vocational/Technical School	273	57.9
	Some College to College Graduate	105	22.2
	Graduate Degree or Higher	83	17.6
Race	American Indian or Alaska Native	15	3.2
	Asian	9	1.9
	Bi-racial	2	0.4
	Black or African American	22	4.7
	Native Hawaiian or Other Pacific Islander	11	2.4
	White	405	87.3
Garden Context	Faith-based	23	4.9
	Government Facility	7	1.5
	Healthcare Facility	16	3.4
	Neighborhood	161	34.0
	Other	25	5.3
	Park	164	34.6
	School	43	9.1

	Senior Center	35	7.4
Region	Midwest	72	15.4
	Northeast	129	27.5
	South	143	30.5
	West	125	26.7
Urban Classification	Other	5	1.1
	Rural	24	5.1
	Suburban	202	42.8
	Urban	241	51.06
Garden Years of Operation	1-5 years	157	33.4
	6-10 years	55	11.7
	Greater than 10 years	95	20.2
	Less than year	16	3.4
	Not sure	147	31.3
Number of Gardeners	Less than 5	15	3.3
	5 to 15	297	62.9
	16 to 30	85	18.0
	Greater than 30	60	12.7
	Less than 5	15	3.2
	Not sure	15	3.2
Garden Size	Less than 0.25 acre	49	10.4
	0.24-.49 acres	65	13.8
	0.5-.99 acres	185	39.3
	Greater than 1 acre	172	36.5
Garden Site History	Vacant Lot	48	10.2
	Park	228	48.5
	Former Industrial Site	44	9.4
	Parking lot	15	3.1
	Farm	20	4.3
	Other	37	7.9

	Don't know	78	16.6
Proximity of garden to a roadway/street	Less than 3 feet	30	6.5
	3-9 Feet	365	78.5
	Greater than 9 feet	70	15.0
Older (pre-1978) housing/buildings near garden	Yes	63	13.4
	No	176	37.5
	Not Sure	231	49.1
Gardening Chemical Practices	Conventional (With pesticides)	52	11.0
	Natural (without known use of pesticides)	253	53.6
	USDA Certified Organic	153	32.4
	Other	14	3.0
Allow Children in the Garden	Never	8	1.7
	Rarely	40	8.5
	Sometimes	54	11.5
	Often	288	61.2
	Not sure	81	17.2

Table 4.2: Direct measures for Soil Testing and Handwashing Items

Construct	Soil Test Item	Mean(SD)	Handwashing Item	Mean (SD)
Attitude[a]	To conduct heavy metal soil testing at my garden during the next growing season would be unimportant-important	4.1(0.9)	Washing my hands after working in my community garden plot is bad-good	4.2(0.6)
	To conduct heavy metal soil testing at my garden within the next growing season would be harmful-beneficial	4.1(0.6)	Washing my hands after working in my community garden plot is unimportant-important	4.1(0.7)
	To conduct heavy metal soil testing at my garden during the next growing season would be worthless-useful	3.7(1.3)	Washing my hands after working in my community garden plot is harmful-beneficial	4.0(1.1)
	Overall Attitude	3.9 (0.8)	**Overall Attitude**	4.1(0.6)
	Cronbach alpha	0.61	Cronbach alpha	0.62
Subjective Norms[b]	People who are influential in my garden think that I should conduct heavy metal soil testing in my community garden plot	3.8(1.1)	People who are influential in my garden would approve of me washing my hands after working at my community garden	3.9(0.8)
	I am expected to conduct heavy metal soil testing in my community garden plot	3.5(1.4)	Other gardeners in my community would want me to wash my hands after working at my community garden	3.7(0.9)
	I feel social pressure to conduct heavy metal soil testing in my community garden plot	2.7(1.2)	It is expected of me to wash my hands after working at my community garden	3.7(1.2)
	Overall Subjective Norms	3.4(0.9)	**Overall Subjective Norms**	3.8(0.8)
	Cronbach alpha	0.68	**Cronbach alpha**	0.64
Perceived Behavioral Control (PBC)[c]	I am confident that I could conduct heavy soil testing in my community garden if I wanted to	3.9(0.8)	I am confident that I could wash my hands after working at my community garden if I wanted to	4.1(0.7)
	Heavy metal soil testing in my garden plot is not under my control-under my control	3.1(1.2)	Washing my hands after working in my community garden plot is very difficult-easy	3.6(0.9)
	Heavy metal soil testing in my garden plot is very difficult-very easy	3.1(1.0)	Washing my hands after working in my community garden plot is time consuming-not time consuming	3.4 (1.2)
	Whether I conduct heavy metal soil testing at my garden plot is entirely up to me	2.5(1.0)	Washing my hands after working my community garden plot is not under my control-under my control	4.1(0.7)
	Overall PBC	3.4(0.8)	**Overall PBC**	3.8(0.7)
	Cronbach alpha	0.65	**Cronbach alpha**	0.75

Intention[d]	I am willing to conduct soil testing at my garden plot in the future (e.g., within the next growing season to sometime next year)	4.2(0.92)	I am determined to wash my hands after working in my community garden during the next growing season	4.2(0.91)
	I expect to conduct heavy metal soil testing at my garden plot in the future	3.7(0.88)	I want to wash my hands after working in my community garden during the next growing season	4.0(0.74)
	I am determined to conduct heavy metal soil testing at my garden plot in the future	3.6(0.91)	I expect to wash my hands after working in my community garden during the next growing season	3.9(0.77)
	Overall Intention	3.8(0.79)	Overall Intention	4.1(0.71)
	Cronbach alpha	0.76	Cronbach alpha	0.84
		n (%)		**n (%)**
	Low Intention	125(26.2)	Low Intention	93(19.6)
	High Intention	332(73.8)	High Intention	382 (80.4)

a: 1=negative attitude (e.g., unimportant, harmful); 5= positive attitude (e.g., important, beneficial); b. 1=low subjective norm influence (strongly disagree); 5 high subjective norm influence (strongly agree); c. 1=low pbc (e.g., strongly disagree, difficult) 2=high pbc (e.g., strongly agree, easy)
d. 1-3.5= low intention (strongly disagree); >3.5= high intention (strongly agree)

Table 4.3: Spearman correlations among TPB Variables

	1	2	3	4
1. Soil Testing Intention	1			
2. Attitude	0.31*	1		
3. Subjective Norms	0.57*	0.12*	1	
4. Perceived Behavioral Control	0.17*	0.58*	0.04	1

	1	2	3	4
1. Handwashing Intention	1			
2. Attitude	0.40*	1		
3. Subjective Norms	0.50*	0.49*	1	
4. Perceived Behavioral Control	0.29*	0.74*	0.39*	1

*p<0.05

Table 4.4: Predictors of Soil Testing and Handwashing Intention

	Soil Testing		Handwashing	
Predictor	OR[a]	[95% Conf. Interval]	OR[a]	[95% Conf. Interval]
Attitude	4.12*	[2.31,7.36]	3.09*	[1.30,7.33]
Subjective Norms	3.02*	[1.82,5.01]	4.58*	[2.27,9.25]
Perceived Behavioral Control	1.86*	[1.09,3.15]	2.92*	[1.23,6.96]
Garden Context	1.10	[0.9,1.34]	1.07	[0.87,1.32]
Income	1.71	[0.68,4.3]	1.89	[0.60,5.99]
Region	1.09	[0.78,1.53]	0.89	[0.64,1.23]
Age	0.79	[0.52,1.19]	0.92	[0.54,1.57]
Race	0.89	[0.52,1.5]	1.45	[0.76,2.78]
Education	0.11*	[0.05,0.25]	0.23*	[0.08,0.61]
Chemical Practice Methods				
Natural (Reference)				
Conventional	0.20*	[0.08,0.49]	0.10*	[0.03,0.30]
USDA Certified Organic	0.57	[0.2,1.65]	1.60	[0.46,5.64]
Garden Site History	1.12	[0.93,1.36]	1.03	[.0.85,1.26]
pseudo R^2		0.50		0.49

*p<0.05, [a] Adjusted for all covariates in table

Logistic regression models were fit using robust standard errors. For all contextual variables (i.e., garden context, income, region, age, race, education, garden site history), the reference value was set at the most frequent category.

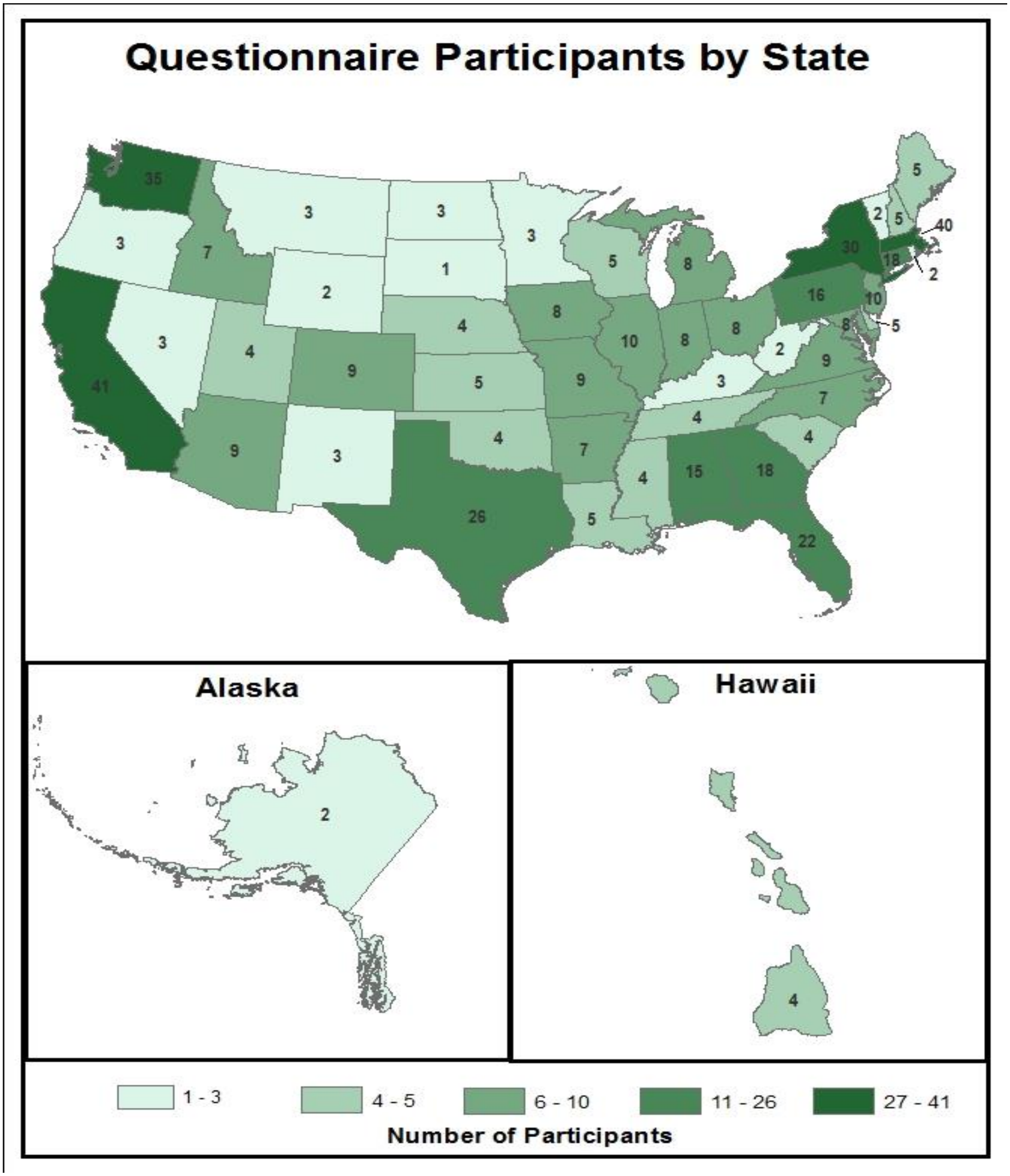

Figure 4.1 Questionnaire Participant Community Garden locations

Chapter 5: Summary & Conclusions (Synthesis Chapter)

The United Nations Food and Agriculture Organization estimates that 800 million people worldwide are involved in urban agriculture in some aspect (United Nations Food and Agriculture Organization (FAO), 2018). Community gardens are a primary type of urban agriculture that have grown in popularity, particularly in schools and other settings. Several studies have quantified soil contaminant concentrations in community gardens and urban soils (M. L. Kaiser et al., 2015a; Latimer et al., 2016; Marquez-Bravo et al., 2016; Mitchell et al., 2014b; Moller et al., 2018), and practices have been recommended to reduce soil exposures (Kessler, 2013; U.S. Environmental Protection Agency, 2014). However, there is less research on the underlying determinants of exposure mitigation behaviors. Therefore, a gap in the literature exists regarding characterization of behavior and contexts to support effective research translation and interventions. To break the cycle of environmental health disparities, identification of variables, which impede or facilitate adverse exposures at individual, community, and policy levels is needed. Therefore, this study sought to contribute to the evidence base for intervention development by examining factors that influence attitudes, social norms, perceived behavioral control, and risk perceptions related to soil contamination among community gardeners. Using an exploratory mixed-methods approach grounded in the Theory of Planned Behavior, this study investigated factors that influence community gardeners to conduct behaviors to reduce their exposures to heavy metal soil contaminants with the following primary aims: 1) Identify community gardeners' salient beliefs related to soil testing as well as perceived gardening benefits; 2) Characterize gardeners' perspectives on best management practices (composting, mulching, and hygiene-related behaviors) to reduce soil contaminant exposures; and 3) Quantify the impact of attitudes, subjective norms, and perceived behavioral control on intention to test soil among U.S. community gardeners.

The qualitative phase of this research utilized five focus groups to explore the behavioral, normative, and control beliefs related to soil testing among Atlanta community garden leaders (Chapter

2). Additionally, the underlying gardening motivations, risk perceptions, and site history themes were examined to provide contextual data as to why some gardeners may implement testing while others do not. Behavioral belief findings suggest that gardeners' value heavy metal soil testing as a method to improve the soil quality and grow healthy food; however, primary disadvantages were related to potential liability, garden stigma concerns, and amount of time to collect, ship, and analyze soil samples. Normative beliefs or potential social pressures to conduct soil testing were from gardening peers, government, university, and relevant advocacy organizations. Participants expressed that control beliefs were centered around liability, costs, accessibility, and concerns related to test results representativeness and interpretation. Similar to other studies, findings revealed that gardening benefits and motivations were community engagement, cultural identity, environmental stewardship, food creation, and children's education (Al-Delaimy & Webb, 2017). When gardeners think about hazards, chemical contaminants were not at the forefront of their concerns. Physical hazards such as theft, ergonomics and pests were more commonly mentioned. Information methods for gardening hazards included university websites, social media, online forums, internet searches, and their community garden training events and outreach activities. Focus group participants shared that they received most of their information about gardening hazards from their gardening peers, Extension Service, and non-profit organizations. Additionally, some participants expressed concerns about past dumping and other land use activities at their garden site but lacked information on how to confirm garden site history.

Qualitative data findings also revealed the advantages/disadvantages, advocates/non-supporters and barriers/facilitators regarding three safe gardening practices typically conducted as part of gardening maintenance phases: composting, hygiene behaviors, and mulching (Chapter 3). Composting and mulching benefits were associated with improving soil quality through addition of organic material (composting) and moisture retention (mulching). A key finding was that study participants did not associate composting and mulching as practices to reduce exposure to soil contaminants. Conversely, disadvantages of composting and mulching were related to potentially introducing contaminants, weeds, and pests. The advantages of handwashing were related to reducing soil exposure, but a disadvantage was minimizing exposure to good microbes. Hygiene behavioral challenges included access to potable water, availability of gloves and wipes, and concerns about minimizing exposure to salubrious bacteria. Depending on their respective views, teachers and garden leaders were mentioned as supporters and non-supporters of the behaviors. Data illustrated that more funding, volunteers, and training are needed to promote these behaviors.

The study also quantified the contribution of attitudes, subjective norms, and perceived behavioral control with intention to soil test and hand wash after gardening among community gardeners across the United States (Chapter 4). Most participants indicated that they intended to conduct these behaviors. Seventy four percent of survey participants said that they intended to test their soil in the next growing season, and eighty percent of gardeners indicated that they intended to regularly wash their hands after gardening. Attitudes, subjective norms, and perceived behavioral control were all statistically significant predictors of soil testing and handwashing intention. Additionally, education and chemical practices influenced whether participants intended to conduct the behaviors. Lower education and agricultural methods without chemicals were associated with higher intention.

Cross-aim analysis: Synthesis of qualitative and quantitative findings

This section synthesizes the empirical findings from the qualitative and quantitative phases of the present study to address the primary research aims. The qualitative and quantitative data were complementary and provided a comprehensive exploration of the values and meanings associated the safe gardening behaviors (e.g., “the why”, “in what context”) as well analysis of predictive variables and assessment of associations (e.g., “the how many” and “to what extent”). Findings from the qualitative phase presented a thorough understanding of motivations and experiences of community gardeners as well as narratives to characterize how gardeners perceive gardening hazards and protective behaviors.

The qualitative phase also allowed for development of relevant survey questions grounded in TPB constructs as well as beliefs and themes expressed in gardeners' own words. Survey analysis allowed for measurement and statistical testing to quantify variables that would influence behavioral intention. Conceptualizing the meaning of these variables was strengthened through the qualitative data, and the survey data further validated focus group themes. Shared themes from the qualitative and quantitative data were reflected in the following areas: 1) Positive attitudes toward soil testing and handwashing; 2) Influencers of the behaviors; 3) Lower perceived behavioral control for soil testing; 4) Risk perceptions; and 5) Site history and factors that could contribute to higher contaminant levels. Quotes reflecting themes and supporting survey data are presented in Table 5.1.

Attitudes toward soil testing in the survey were positive overall with most participants agreeing that soil testing was beneficial (88%), important (76%), and useful (61%). Attitude also had the strongest influence on soil testing intention (OR= 4.12, 95% CI: 2.31, 7.36). The focus group participants shared favorable attitudes and behavioral beliefs that soil testing provides several advantages related to soil quality, but participants also revealed some disadvantages with liability as a foremost concern. Survey participants ranked government public health agencies followed by government environmental agencies as the most influential supporters of soil testing. In contrast, focus group participants more frequently mentioned local nonprofit groups and gardening training programs (e.g., Truly Living Well Center for Urban Agriculture, Georgia Organics) as primary supporters and influencers of soil testing. Detractors of soil testing, such as those responsible for dumping chemicals or concerned about property values, were discussed in the focus groups as well.

Perceived behavioral control and control beliefs related to soil testing findings had the strongest intersection from the focus group and survey data. Study results complement previous findings, which suggest that community gardeners experience barriers to executing gardening practices that could minimize contaminant exposures (Chaifetz et al., 2015; Henson, Tenorio Fenton, & Tikalsky, 2017; Kim et al., 2014; Wong, Gable, & Rivera-Núñez, 2017). Focus group participants expressed barriers such as cost, test interpretation challenges, and lack of time, volunteers, and training. Financial and training barriers to soil testing were corroborated in the survey: Seventy percent of participants agreed that soil testing is expensive and 80% agreed with the statement, "When I have the financial resources needed to conduct soil testing in my community garden plot, I am more likely to conduct soil testing."

Only 23% of survey participants thought that there were not enough resources for interpreting heavy metal soil testing results. However, focus group participant data revealed that the current resources do not adequately explain the results — reflecting quality and usefulness of the training resources despite the quantity of resources available. Focus group and survey data also reflect a relatively low to neutral perceived behavioral control to conduct soil testing. Sixty-six percent of survey participants agreed with the statement, "Whether I conduct heavy metal soil testing at my garden plot is not entirely up to me," and over half (54%) of participants indicated that soil testing is somewhat or not under their control. However, community gardeners may have the self-efficacy to have the testing done (85% agreed that they are confident that they could conduct heavy soil testing in their community garden if I wanted to). This finding reflects that gardeners believe they can conduct soil testing and intend to test their soil if identified barriers are addressed.

Like soil testing, handwashing practices among gardeners were viewed positively in the focus groups and surveys. Focus group participants typically shared more advantages of handwashing than disadvantages, and survey participants agreed that handwashing was good (95.5%) and important (88%). However, only 55 % of survey participants agreed that handwashing was beneficial, which may be potentially supported by some focus group sentiments that handwashing could reduce exposure to healthy bacteria and that we are living in a "too sanitized" society. Subjective norms served as the strongest influence of handwashing intention (OR=4.58, 95% 95% CI=2.27,9.25) among survey participants. Eighty two percent of survey participants agreed that "People who are influential in my garden would approve of me washing my hands after working at my community garden." Influential people may depend on the garden setting and context. For example, focus group participants frequently mentioned that teachers can be supporters or non-supporters of handwashing in school gardens. Most survey participants concurred that handwashing was very easy (65%) and under their control (89%). Focus group data indicated that perceived behavioral control and self-efficacy of handwashing could be strengthened by having handwashing stations and other materials on site, cues to action such as handwashing reminder signs, and garden management enforcing and/or modeling the hygiene behaviors.

This survey revealed pertinent summary statistics about unawareness related to garden characteristics and site history that may influence contaminant concentrations and participant vulnerability. For example, about half of participants were unaware whether their garden was near older housing that may have lead paint, 17% were unaware of their garden's previous site use, and about 31% were unaware of how long their garden had been established. While some focus group participants had knowledge of these garden characteristics, those who did not were unsure of resources to obtain information related to garden characteristics and address concerns regarding site history and potential dumping as well as current land use challenges like runoff from nearby industrial and residential areas. Both survey and focus group participants expressed that children have access to the garden space which underscores the importance of these behaviors among this vulnerable population.

Supporting previous community garden research, the survey and focus group data results indicate that gardeners have diverse perceptions regarding gardening risks, but heavy metal exposure from soils is not a salient concern. Focus groups participants indicated that ergonomics, pests, and safety/theft were prominent hazards. Survey data reveal that less than half (41%) agreed with the statement, "I have concerns that community gardeners may be exposed to heavy metal contaminants through community gardens" and forty-seven percent agreed with "I think that it is unlikely that I would become ill from exposure to heavy metal soil contaminants in a community garden." In contrast to previous studies that indicated demographic variables such as race (Wong et al., 2018) and gender (Guo et al., 2018) were associated with contaminant risk concerns among gardeners, this study did not reveal a strong correlation with these variables. In contrast, most (90%) participants worked, and of those who worked 39% indicated that their job involved working with chemicals and 82% indicated that their primary job was with gardens. Therefore, these job characteristics could potentially influence perspectives related to garden contaminant risks.

Study Limitations

This study has several limitations which should be considered in context of the findings. First, common challenges in focus group research such as social desirability bias and deference to perceived dominant members within the focus group could result in findings not truly reflective of participants' experiences. Second, this study developed survey questions grounded in TPB based on focus groups of Atlanta community garden leaders, and the beliefs of Atlanta community garden leaders may not fully mirror beliefs and experiences of community gardeners in Atlanta or across the U.S. For example, Atlanta has a growing population of refugee gardeners. However, focus groups did not include non-English speakers or specifically target these gardeners. Therefore, their experiences may not be adequately reflected within the scope of this study. Atlanta community garden leaders may have different perspectives, directed training, and long-term experience that influence their perspectives on soil contaminant exposures. Due to their experiences, views of focus group participants may differ from survey participants. Survey participants were mostly white, male garden plot owners/gardeners (67%), and about half of them had 1-5 years of experience; survey participant perspective may not also adequately represent the views of community gardeners across the U.S. Additionally, Atlanta's industrial and political history as well as other factors such as land use policies and social determinants may differ from many other U.S. areas. However, the objective of the qualitative research was not generalizability, but the ability to potentially apply the findings in parallel settings and contexts and to develop survey questions grounded in a behavioral theory from a gardener stakeholder perspective. Given that these survey questions have not been previously tested within a national audience, pilot testing could be done regionally.

Next, survey results focused on intention rather than behavior. Gardening visits and observation may have better quantified whether these behaviors were conducted among the general population. Observations could confirm self-reported data as well as have examined sources of contaminants such as treatable wood, railroad ties, proximity to older housing, and other characteristics for soil contaminants. Another limitation is that the survey did not collect community garden name or address to preserve anonymity of the participants. Focus group data and survey pilot testing revealed that garden participants may not know the garden exact address and used land markers for garden location. However, an undesired consequence of the lack of garden GIS identifiers may be a dependence among the participants who were from the same community garden or who may have been connected through other means. However, examination of TPB variables among gardeners who lived in the same state did not reveal strong correlations. Finally, the cross-sectional design limited causality analysis. Longitudinal studies may provide a stronger understanding of the effect and associations of TPB constructs over time.

Implications of findings

This study contributes to the investigation of psychosocial variables that should be considered for safe gardening behavior assessment, intervention planning, and program evaluation. Implications of these findings apply to the Theory of Planned Behavior, community-engaged research and environmental justice, exposure science, and policy/translation of safe behaviors.

Theoretical Implications: Although TPB constructs have been applied to other environmental-related behaviors (De Leeuw, Valois, Ajzen, & Schmidt, 2015; Han et al., 2010; Nigbur, Lyons, & Uzzell, 2010), this is the first time the TPB approach has been applied to explore safe community gardening behaviors. The Theory of Planned Behavior was utilized for the framework of this study with the following considerations: 1) previous research that demonstrated strong predictive validity for a variety of behaviors; 2) clear guidelines on survey development and scoring; and 3) constructs for intervention development and evaluation. While TPB proved to be an influential framework to explore salient beliefs and behavioral intention among gardeners, criticisms applicable to the present study include its individual behavior focus and potential interactions among belief constructs. For example, history of housing discrimination policies and other social determinants of health may contribute to certain populations living in or proximate to older housing and other characteristics that influence adverse exposures beyond individual behaviors related to mitigation of those exposures. Consistent with individual level critiques of health behavior change, multilevel interventions and research may be needed to fully address the barriers and facilitators identified in this study to protect gardeners from soil contaminant exposures (Golden & Earp, 2012).

In this study, preliminary structural equation modeling work revealed potential collinearity among soil testing belief constructs. While this collinearity may reflect how survey items were constructed and measurement calculations, a challenge of TPB is that behavioral, normative, and control beliefs may interact with each other and multiple causal pathways should be considered. This finding is consistent with research that has expanded the TPB with concepts from other theories and tested interactions among constructs (Appiah-Brempong, Harris, Newton, & Gulis, 2018; Gourlan, Boiche, Takito, Fregeac, & Cousson-Gelie, 2018; Kothe & Mullan, 2015; J. R. Smith et al., 2007). For example, expansion of the model to better characterize the role of risk perception, policies (such as real estate laws requiring disclosure of soil lead tests results), community-based interventions and the interaction of these factors with TPB constructs. Although there has not been much theory-driven work on soil testing interventions, a systematic review of handwashing intervention studies indicated that community-based approaches that incorporate theory-driven components and diverse promotional methods are most effective (De Buck et al., 2017).

Community-Engaged Research and Environmental Justice Implications. Community involvement and exploration of underlying psychosocial factors in environmental health research is critical to promote sound science (rigor), to develop appropriate questions and hypotheses (relevance), and to effectively disseminate and translate findings (reach) (Balazs & Morello-Frosch, 2013; Joyce & Senier, 2017). The importance of community engaged work has been accentuated by federal agencies such as the National Institute of Environmental Health Sciences which require community engagement cores as part of their funded programs and strategic plan (Finn & Collman, 2016). Although this research was not directly community driven, research aims were influenced by key informants from the Atlanta local food movement. After hearing leaders' concerns related to garden sustainability, food sovereignty/justice, and economic empowerment, the initial research changed from focusing solely on soil testing to inclusion of other behaviors that contribute to garden sustainability. Additionally, perspectives from focus group participants and HERCULES Stakeholder Advisory Board (SAB) members were incorporated in the survey development phase. These steps were vital in ensuring survey items were easily understood, and this approach could be applied further in development of survey items and construct scales. Given that community gardens involve communities in different contexts by their nature/definition, qualitative approaches such as focus groups serve as tool to ensure their voices are heard and incorporated into the study design and findings.

Environmental justice implications of this study relate to the meaningful involvement of community gardeners and other stakeholders to impact garden decision making and soil management. It has been well documented that built environment and social inequities can contribute to increased exposures to hazardous waste sites, air pollution, harmful odors, landfills, illegal dumping, food deserts and other stressors among minority and low-income communities (Morello-Frosch, Zuk, Jerrett, Shamasunder, & Kyle, 2011). For example, Atlanta has racial, economic, and food access disparities that affect where contaminants are located, who has access to certain resources, and who has the decision-making and political power. Based on analysis of 2016 American Community Survey data, Atlanta was ranked as the U.S. city with the highest level of income inequality (Berube, 2018). Previous research has demonstrated a disproportionate distribution of pollution in Atlanta poor and minority communities (Greenlaw, 2012; R. Johnson et al., 2016).

Community gardens and other forms of urban agriculture have been implemented as a tool to address food insecurity, systematic displacement, and municipal disinvestment in underserved populations, and the placement of these gardens may occur on vacant lots, former industrial areas, and other sites where land is available and reasonably priced. Communities that are already overburdened with environmental contaminants, psychosocial stressors, and other cumulative risks, may not have time, volunteers, interest or other resources for soil testing. Therefore, application of these study findings can contribute to more efficient interventions by targeting attitudes, barriers, influential groups, that can influence soil contaminant exposures. Even in the potential absence of soil contaminant hazard, the precautionary principle should be followed, particularly for vulnerable populations such as children and immunocompromised. According to the CDC School Health Policies and Practices Study, about 20% of school districts in the study are using produce from school gardens. Although USDA recommends good agricultural practices (GAPs) and Good Handling Practices (GHPs) for school gardens, these practices are not required or enforced in many areas in the U.S. Since school gardens or playground soils are not often required to be tested for heavy metals, vulnerable populations may be at risk to harmful soil exposures. As discussed in previous chapters, volunteers can help with soil testing and other safe practices as educational components for gardens involving children.

***Exposure Science Implications*:** Environmental health risks have been defined as a function of hazard and exposure. In the context of soil contamination, reducing hazard could be through remediation or removal which is often expensive and time consuming. Therefore, practices focused on limiting exposure and understanding soil concentration levels through practices as described in this study can reduce risk expeditiously. An anecdotal example of this implication relates to slag that was found in a vacant lot in an Atlanta westside community where children may have contact with the soil and slag. While remediation and sources of the slag are investigated, behaviors described in this study can be conducted in the interim to minimize exposures. Focus groups and other qualitative approaches have a key role in exposure sciences since these methods can be applied to understand contexts and experiences of how gardeners encounter contaminants and conceptualize consequences of contaminant exposure and useful information for developing interventions. Other studies have emphasized the importance of understanding the social, economic, and political determinants that contribute to unequal individual exposures in environmental health research (Joyce & Senier, 2017; Senier, Brown, Shostak, & Hanna, 2017), and the implications of these determinants can be explored through qualitative research. Focus groups in this study examined gardening motivations and hazard perceptions which can be leveraged to change circumstances that contribute to exposure. For example, gardeners' concerns about theft and safety in the garden leads to exploration of other community concerns that can be targeted for joint interventions such as fenced in areas that address both physical safety in terms of garden access and fenced in areas/sheds for storage of personal protective equipment (e.g. gloves, wipes) to prevent harmful soil exposures.

***Policy Implications*:** This study has direct policy implications for community garden stakeholders such as community garden/urban agriculture grant organizations, early childhood education programs, urban planners, and public health advocates. Policies related to provision of data about both present and past sources of gardening hazards based on garden location could facilitate a stronger focus on soil contamination reduction. For instance, raised beds constructed with untreated wood and imported soil are often lauded to reduce harmful soil exposures. However, contaminants from air pollution can deposit on to soils — underscoring the importance of garden siting hazards proximate to heavy traffic areas (Amato-Lourenco et al., 2016). Additionally, garden site history should be shared with new gardeners during garden leadership transitions to guide soil quality management and testing. Examples of sharing this information could include a site history book or timeline. Gardening support organizations may be able to provide resources such as Sanborn maps for gardeners to research previous land use.

Community garden stakeholders should be engaged to improve soil testing access, provide guidance of clean soil/compost purchasing options, and facilitate effective training interventions. First, confronting barriers to soil testing such as liability concerns and fear of frightening community gardeners is needed. For example, mandatory disclosure of soil lead levels for real estate properties and other regulations may deter gardeners from soil testing (S. Johnson et al., 2016) due to potential consequences such as stigma, decreased property values, and required clean up. Therefore, gardeners and other stakeholders should be equipped for handling outcomes created by increasing soil testing access. Second, organizations can also require soil testing, donate soils/compost that have been tested, or provide soil testing and training. For example, soil testing has been used as a subsidy incentive for farmers to implement sustainable practices (Daxini et al., 2018). Commercial compost/soils that have the Organic Materials Review Institute or the U.S. Composting Council Seal of Testing Assurance logo have been tested for metals and could be distributed to gardeners. Third, engaging children, building communities, and environmental stewardship were frequently mentioned in this study as garden benefits/motivations; therefore, combining these benefits with a training program could synergize efforts. For instance, school garden programs have used as a multi-intervention effort combining safety and learning to improve nutrition, hygiene, and agricultural practices (Yang et al., 2017). Integration of chemical soil contaminant information into garden training that typically centers on microbial risks and foodborne illnesses could help reframe soil chemical testing as part of sustainable practices to grow healthy food.

Study findings also warrant development on clear, consistent guidelines regarding threshold levels for garden soil contaminants as well as bioavailability assessments to quantify the extent that contaminants are absorbed in human tissue. Since soil testing contaminant thresholds and follow up actions may vary by jurisdiction, clear guidelines and interpretation of soil testing results should be developed to combat uncertainties. Although EPA Soil Screening Levels (SSLs) are often used as guidelines for urban gardening, SSLs were initially developed for Superfund site exposure pathways and residential scenarios related to bare soil play areas for children. States can choose to adopt these SSLs for gardens or pose more conservative thresholds. For example, the EPA SSL for lead is 400ppm, but the University of Georgia Extension Office classifies soil lead levels between 75-400ppm as potential risk based on Georgia Environmental Protection Division's Rules for Hazardous Site Response (Varlamoff, Lessl, Sonon, & Bauske, 2016). An EPA Technical Review Workgroup has suggested that soil lead levels between 100 to 400 ppm present potential risk in garden exposure scenarios (U.S. Environmental Protection Agency, 2014). Bioavailability assessments, improved exposure scenarios, and better understanding of soil contaminant background levels across the U.S. can provide the basis of more consistent risk thresholds for urban community garden soils.

Future Research and Directions

Future research may involve development of interventions to reduce soil contamination exposures based on study findings. Studies of pre-post interventions and behavior change coupled with soil contaminant bioavailability studies are warranted. Other studies have expanded the TPB with risk perception and policy measures to better explain behavioral intention of sustainable practices among farmers (Daxini et al., 2018; Yazdanpanah, Hayati, Hochrainer-Stigler, & Zamani, 2014). Therefore, development and validation of a risk perception variable to supplement the TPB as well as examination of other influential factors at the individual, community and policy levels can more holistically contextualize gardeners' exposure mitigation behaviors. Case studies and policy analyses of cities that have implemented and required soil testing and guidelines should be studied longitudinally to understand long-term impacts on soil contaminant concentrations and human health.

Future plans are to continue additional analyses of the community garden dataset by publishing compost survey data (not reported in this dissertation) as well as working with Atlanta community garden stakeholders to develop and disseminate community garden information via activities such as the Atlanta Science Festival and ATSDR SoilSHOPs.

Conclusion

The aims of this study jointly examine factors that influence community gardeners' behavior related to safe gardening practices in Atlanta, GA and across the United States. Although behaviors can be determined by many variables, this study methodically demonstrated that attitudes, subjective norms, and perceived behavioral control significantly influence behavioral intention to soil test and wash hands after gardening. The study provides evidence for development of tailored interventions that encompass motivations and psychosocial influences. The research demonstrated that soil contaminants are often not foremost gardening concerns; however, gardeners demonstrated strong intentions to conduct mitigation behaviors for reasons other than reducing exposure to soil contaminants. Although mixed methods approaches are not traditionally used in environmental exposure studies, the combination of qualitative and quantitative data provided improved understanding of gardener contexts, exploration of perceived risks, and quantification of behavioral intentions. Study findings have implications for behavioral theory, environmental justice, exposure science, and policy. Promoters of community gardening efforts should incorporate activities and policies to ensure children and vulnerable populations can overcome barriers to safe gardening practices. With this approach, the benefits of community gardens can be maximized while also protecting gardeners and consumers from unintended consequences.

Table 5: Comparison of Qualitative and Quantitative Themes

Construct	Example Focus Group/ Survey Quote	Example Survey items
Soil Testing Behavioral belief/ Attitude	"I think if you know what's there, it lets you know if there's a problem that you might want to deal with in terms of heavy metals and pesticides…If you know what's there in terms of the nutrients, then you've saved yourself money by not over fertilizing." "And then there's the added thing of you know when your soil is out of whack and your vegetables aren't growing right…so you avoid the problem by starting out right with knowing what's in there."	To conduct heavy metal soil testing at my garden during the next growing season would be important (76 % agree)
		To conduct heavy metal soil testing at my garden during the next growing season would be useful (61% agree)
		If I conduct heavy metal soil testing in my community garden, I may be able to detect potential soil problems within the growing season (71% agree)
		Conducting heavy metal soil testing will help me to understand the baseline of my garden's soil quality (78% agree)
Soil Testing Normative belief/ Subjective Norms	Non-supporters: "P: Yeah. Companies that have to get rid of stuff. P: Yeah. They're dumping, and they know they're dumping. P: I don't know, I imagine it would have to be in really high concentrations, but anybody interested in maybe like the property values."	I am expected to conduct heavy metal soil testing in my community garden plot (60% agree)
		I feel social pressure to conduct heavy metal soil testing in my community garden plot (36% agree)

Soil Testing Control belief/ PBC	"They give you parts per million and a lot of times there's not a definite level that's acceptable, because nobody really knows how much is acceptable, so they'll say it's EPA limits or below EPA limits or something, but you still don't know if that's safe." Survey comment: "I am a little embarrassed to say that the perceived difficulty and expense of soil testing has kept us from doing it. I know that we "should," according to public health authorities, though most people in my garden don't think it's necessary. I think the soil in the garden is probably pretty safe; my son eats produce from the garden and his lead levels are tested as a matter of course in this state, and they are not elevated. But if it were trivially easy to do, I definitely would have done it. I know I probably could look up a place to get the testing done, but I also wonder how meaningful the results would be to me or if it would be hard to know what level of risk they actually represent, and I wonder whether there is realistically anything I could do, beyond further amending the soil with compost (which I already do regularly) to actually change the lead content of the soil. There is a lot of lead in the city...that is sort of a fact of life in my neighborhood. Survey comment: Even as someone who works in community gardens, does soil testing, helps people interpret results - it's hard to find reliable, simplified, resources about the risks of soil contamination. There are so many factors - how much contamination is available to be taken up by plants and people? What are the safe limits we should be holding to? No one agrees on the limits. Sampling soil is not an exact science... And that it's always a good idea to practice safe gardening habits. Overall, do the benefits of gardening, exercise, eating veggies out weigh the negatives of contaminated soil?	Heavy metal soil testing is expensive (71% agree) When I am aware of heavy metal soil testing facilities, I am more likely to conduct soil testing (79% agree) There are not enough resources/training on how to interpret heavy metal soil testing results (23% agree)

Handwashing Attitude	"There are hoses at our garden, and I typically wash my hands before I get in the car just because I don't want to get dirty hands all over my steering wheel. (laughs) Once again, I'm trying to keep -- have less housework, you know? Less cleaning work. But I think most people do wash their hands just because there's dirt under their fingernails and they're a little more comfortable if they've washed their hands before they leave, but it's not a handwashing station. It's a hose." "I'm notorious. I like to get my hands dirty, so I want the kids playing in the dirt. I want them to feel it, smush it, because after a while they start playing anyway, so I'm not a huge stickler for hygiene in the garden." "It's levels of how serious you want to get about this, and I tend to think that we've gotten into a very sanitized living where we don't want the least little bit of dirt, and I think sometimes people have more allergies and things like that because our bodies have stopped building up that immunity."	Washing my hands after working in my community garden plot is important (88% agree) Washing my hands after working in my community garden plot is good (95.5%)
Handwashing Subjective Norms	"The actual teacher at one of our schools wanted them to get dirty, because they're affluent children and they don't get dirty very much apparently" And the teacher is going to take them to wash their hands.	People who are influential in my garden would approve of me washing my hands after working at my community garden (79% agree)
		Other gardeners in my community would want me to wash my hands after working at my community garden (81% agree"
Handwashing PBC	"I also think like just education around foodborne illnesses and proper signage too, just making it easy, like mentally easy enough for everyone to see -- You know, because I'll forget to	I am confident that I could wash my hands after working at my

	wash my hands or something like that, but if there's a sign constantly reminding you or something like that then it takes less mental energy and it's more likely to get done." we also are near a community center, so we have access to [potable] water. But other places that I know of may not have access to running water on the site."	community garden if I wanted to (89% agree) Washing my hands after working in my community garden plot is very easy (65%agree)
Risk perception	"I don't think they worry about heavy metals. I worry about heavy metals, but I don't think they do, and they're interested in what do I need to add to make this soil healthier so I can grow vegetables." "I think there are some people who feel that it would test everything, we worry too much about everything, and end up spending money on things rather than just getting on with it." "I think it might cause some fear in your everyday gardener to not rent a bed if they felt like there was danger that it had toxins or metals in it…if we didn't reassure them that raised beds have clean soil from a good source… it might deter some people from renting a bed, which we -- like many gardens, are sustained by renters " "…but you've got to be careful not to scare and upset people unnecessarily, because sometimes these things with the environment get blown way out of proportion."	I have concerns that community gardeners may be exposed to heavy metal contaminants through community gardens (40% agree)
Site History and other garden characteristics that could contribute to contamination	"I wouldn't say necessarily for us they would know like the complete history, so maybe you know the previous owner or whoever has been, you know, at the present time who owns it or whatever. I don't think that most people are looking like at the entire land history" "Well, even with farming though, I mean, there's arsenic and other things that farmers used that could be in the soil, so you never know. I'm glad you're doing this. That's one of the	About half of participants reported garden site history as a park site, 10% at vacant lot, 9.4% industrial site and 16.7% didn't know the site history. Only 11% of respondents reported that they used

	reasons I wanted to come, because I was curious about what's in the soil." "you still have to be careful, because you know, there's so much dumping these days. I mean, if somebody, it's dark and they don't see anybody, whatever, you don't know, you know?" "So prior to that it may have been a farm, I'm not sure. I just worry more about things that they -- You know, there are things that could have been dumped there" "	conventional methods (involving pesticides) in their community garden. In terms of potential hazards that could contribute to soil contamination, 6% and 49% of participants indicated that their gardens were in close proximity (less than 3 feet) to roadways and were unsure whether their garden was near pre-1978 housing respectively.
Children	"Once a month on Wednesdays, and so yeah, there's a lot of children…so they're in the garden a lot. We do Easter egg hunts for them and playdates, and book readings" "And we have a lot of handicapped children that come. We have two beds that are for handicapped children or handicapped people in general, but so they're there also"	Over half of participants indicated that children are often allowed in the garden.

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