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I am submitting herewith a thesis written by Lauren Ashley Raup-Plummer entitled "SOLID WASTE REDUCTION PRACTICES IN THE SOUTHEASTERN UNITED STATES: PUBLIC PERCEPTIONS AND PROPOSED POLICY CHANGES." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.

Kevin G. Robinson, Major Professor

We have read this thesis and recommend its acceptance:

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SOLID WASTE REDUCTION PRACTICES IN THE SOUTHEASTERN UNITED STATES: PUBLIC PERCEPTIONS AND PROPOSED POLICY CHANGES

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Lauren Ashley Raup-Plummer
May 2013

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DEDICATION

This dissertation is dedicated to

my husband

Mr. Kelly Ross Plummer,

parents

Mr. and Mrs. Kenneth Raup,

and friend

Ms. Maxine Shelly Turner.

Whose love and sacrifice laid the foundation for my higher education.

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ABSTRACT

The U.S. Environmental Protection Agency (EPA) has highlighted the municipal solid waste stream as an area of critical interest due to the non-sustainable nature of existing landfilling or "dumping" practices. In addition to traditionally defined municipal solid waste – commonly referred to as garbage or rubbish – materials such as biosolids, a by-product of wastewater treatment, and animal manure also comprise the landfilled waste stream. Currently, disposal options for biosolids waste materials are limited due to regulations imposed by the EPA to protect waterways and coastal environments, and one of the few alternatives for biosolids disposal is land application. Unfortunately, biosolids land application is a point of contention between the public and local and state governing bodies due to concerns regarding public health and safety risks. To investigate the current public perceptions related to biosolids land application practices, two populations in the south-eastern United States were surveyed. These communities were rural Amelia County, Virginia – a community that historically has been outspoken against biosolids land application– and metropolitan Knoxville, Tennessee – a community that has voiced few concerns regarding land application of waste materials. The first survey sampled 311 adults on questions involving biosolids; the second survey sampled 303 adults in the same region on similar questions involving animal manure applications. These surveys have found that the sampled public perceived animal manure as a lesser health and safety risk than biosolids, and both communities indicated that they were more adequately informed about the risks associated with animal manure than those associated with biosolids. As expected, Amelia County residents who, in general, were more engaged in biosolids issues within their community, responded with stronger attitudes against biosolids reuse than the less engaged Knox Metro residents. A difference in perceptions was also perceived based on gender differences, with female respondents perceiving significantly greater health and safety risks from biosolids applications than males. Overall, gender and location, rather than level of education, contribute significantly to risk perceptions related to biosolids

and animal manure land applications, and community-specific outreach programs will need to be developed to reduce the negative connotation associated with biosolids in the south-eastern United States.

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CHAPTER I: INTRODUCTION

1.1 LITERATURE REVIEW

Recently, the U.S. Environmental Protection Agency (U.S. EPA) highlighted the municipal solid waste (MSW) stream as an area of critical interest due to the non-sustainable nature of land disposal/landfilling practices (TDEC, 2008). Estimates made in 1996 indicate that there were 3581 active landfills in the United States; however, in 2010 the total number of landfills in the United States was only 1908. This number continues to decline as older facilities are closed upon reaching design capacity and new facilities are limited due to siting difficulties and the need for careful planning strategies (U.S. EPA, 1996; U.S. EPA, 2010). With less landfilling facilities being opened and operated, the reduction of landfill volume has become a significant concern in solid waste management. At present, the management of solid waste falls under the ruling of the Resource Conservation and Recovery Act (RCRA), but RCRA focuses on waste classification and landfilling guidelines rather than other alternatives. Despite recent efforts to promote “Reduce, Reuse, Recycle”, the number of MSW pre-treatment facilities remains small, with only 115 waste-to-energy incineration plants and 11 composting facilities being in operation during 2010, and recycling programs remain voluntary. Existing municipal solid waste treatment practices do not promote a sustainable society, and the existing regulation is not sufficient for the implementation of a nation-wide sustainable solid waste program.

1.1.1 Municipal Solid Waste

Municipal solid waste is defined as all non-hazardous waste generated at residential and commercial sites such as personal homes, schools, hospitals, and businesses (U.S. EPA, 2011a). In 2010, approximately 250 million tons of municipal solid waste and 7.6 billion tons of non-hazardous industrial waste were reported in the United States (U.S. EPA, 2011a). However, BioCycle’s “The State of Garbage in America” report indicates that the actual annual MSW generation in the U.S. is closer to 390 million tons (van Harren et al., 2010). The MSW waste stream’s composition can be quite varied, but it is broken into 9 separate categories – paper, food scraps, yard trimmings, plastics, metals, rubber/leather and textiles, wood, glass, and other. These constituents can be used to determine organic, or biodegradable, and non-biodegradable portions of the waste stream, with paper, food scraps, yard trimmings, and wood being loosely considered biodegradable, and plastics, metals, and glass being loosely considered non-biodegradable (U.S. EPA, 2011a). The average composition of MSW disposed of nationwide, courtesy of the EPA's annual MSW report, is found in Table 1 (U.S. EPA, 2011b).

Based on census data, the 2010 United States population was approximately 308,750,000; with a total of 390 million tons of waste being generated in 2010, each American generated approximately 2400 lb of waste to be disposed of over the course of the year (U.S. Census Bureau, 2010; van Harren et al., 2010). Further numbers indicate that an additional 85 million tons of material was removed from the landfilled waste stream in 2010 due to community-managed recycling centers and home composting activities (U.S. EPA, 2011a). While these sustainable methods (recycling and composting) are promoted by the EPA, at this time a mandate for large-scale waste reduction has not been issued by the U.S. government. It is estimated that in 2011 the population in the United States reached about 311,600,000 which would result in the generation of an additional 2.3 million tons of waste (U.S. Census Bureau, 2010). By 2025, the population of the United States is projected to reach 350 million which would mean that approximately 420 million tons of municipal solid waste would be generated annually (U.S. Census Bureau, 2005). In addition to traditionally defined municipal solid waste, materials such as biosolids, a by-product of wastewater treatment, and animal manure are landfilled when reuse options are unavailable. These materials are also closely tied to the rapidly increasing population in the United States.

Table 1. Municipal Solid Waste (MSW) characterization in the United States for 2010.

Constituent	Percentage (%)
Paper	28.5
Food Scraps	13.9
Yard Trimmings	13.4
Plastics	12.4
Metals	9.0
Rubber, Leather, and Textiles	8.4
Wood	6.4
Glass	4.6
Other	3.4
TOTAL:	100

1.1.2 Biosolids

A by-product of wastewater treatment, nutrient-rich biosolids are generated in abundance due to the strict regulations imposed by the U.S. Clean Water Act. The Code of Federal Regulations Title 40 Part 503 defines biosolids as "sewage sludge generated during the treatment of domestic sewage in a treatment works." At present, these materials are approved for disposal via land application, incineration, and landfilling at approved sites (40 CFR 503, 1993). To maintain public health and safety, biosolids are classed as either Class A or Class B as determined by sampled pathogen levels. To receive a Class A designation, the biosolids material undergoes more extensive treatment to ensure that pathogen levels remain below 1000 colonies of fecal coliform per gram of solids; as a result Class A biosolids do not require special handling prior to land application. For reference, Class B biosolids contain concentrations less than 2,000,000 colonies of fecal coliform per gram solids and pose a greater health risk when compared to Class A biosolids (Robinson et al., 2012). The U. S. EPA has taken the position that the biosolids program is low-risk and low-priority, although there have been concerns voiced about the presence of these pathogens in the treated biosolids with regards to risks posed to public health and safety (Lewis and Gattie, 2002).

1.1.3 Animal Manure

Animal manure is a waste stream that has historically been diverted from landfills. Poultry, cattle, and swine manure waste are organic wastes that contain high levels of nitrogen and phosphorus which are key compounds in commercial soil amendments (Evans et al., 2004). Land application provides a sustainable pathway for organic waste disposal, and due to a lack of federal regulations imposed on animal manure, the storage and disposal methods are considerably less refined than those involved in biosolids handling (National Research Council, 2002). This waste is well-received as an agricultural amendment – due to its agricultural origins – and is land-applied throughout the U. S (Edwards and Daniel, 1992; Vellidis et al., 1996).

1.1.4 Municipal Solid Waste Management and Technology

Solid waste engineering governs the development and design of solid waste infrastructure. In the United States, landfilling is the most common disposal method for municipal solid waste (U.S. EPA, 2011b). Landfills are designed to optimize the sited property's total footprint; there are several regulations concerning "buffer zones" that must be accounted for when selecting a property (State of Tennessee, 2011). For a Class I (municipal solid waste) landfill in Tennessee, a disposal facility must have a 100 foot buffer from all property lines with a 500 foot buffer from residences, and a 200 foot boundary for any documented bodies of water such as a spring, lake, or river (State of Tennessee, 2006). These buffer zones are necessary to limit the potential public health issues a landfill imposes on air quality and water quality (40 *CFR* 239-258, 1996a). Once a site has been selected for permitting, the design package must be submitted that includes the facility's predicted active life – the period of time the site will be operating for disposal based on historical waste generation numbers for the serviced community. The completed design must meet all federal and state regulation criteria, and an operations manual that includes the instructions for waste deposition and environmental sampling for air quality and water quality standards must also be submitted (Tchobanoglous et al., 1993).

As mentioned previously, waste streams differ based on their source with over 60% of the U.S. municipal waste stream being composed of biodegradable materials such as paper, food scraps, and yard waste. The remaining 40% of the waste stream consists of non-biodegradable wastes like metals, plastics, and glass (U.S. EPA, 2011a; U.S. EPA, 2011b). This partition of wastes is significant as these streams contribute to very different environmental issues. For example, biodegradable waste, often referred to as green waste, has been recognized by the European Union and the EPA as the leading contributor to leachate and methane formation in landfills due to the high moisture contents and readily degradable chemical make-up of this material (European Commission, 1999; U.S. EPA, 2011d). Alternatively, non-biodegradable constituents such as metal wastes can decay in the presence of excess moisture allowing toxic compounds to be removed from the waste and create a potentially hazardous chemical leachate (Ward et al., 2005). Current engineering technologies have been implemented to reduce the risks of leachate and methane gas formation by providing vents and leachate collection systems throughout the landfill. Additionally, the EPA mandates that these facilities being monitored for breakthrough contamination using a system of monitoring wells located down-gradient of the landfill facility (State of Tennessee, 2006).

Reduction of landfill volume has become a significant factor in the development of a sustainable society. The practice of landfilling, or dumping, is considered non-sustainable as these methods are a form of waste disposal and do not provide reuse benefits. While the concept of a zero waste society has been introduced and well-received, the U.S. EPA has recognized that a true zero waste society cannot be achieved and the program's target is to instead reduce total waste production (U.S. EPA, 2009; Bard, 2011). A zero waste society is one in which all waste materials are collected for reuse and recovery rather than disposed of. Overall, the science behind existing solid waste management infrastructure is not sufficient to promote a sustainable lifestyle, much less a zero waste infrastructure. The underlying scientific areas governing this issue and its associated regulations are public health, solid waste engineering, and economics.

A key factor in changing solid waste management practices involves whether or not the proposed management changes are cost effective. Costs of landfilling include operational costs, collection costs, and environmental costs required to maintain proper permitting. Operational costs include equipment and personnel that move waste from the tipping station to the active phase of the site and in certain cases security costs to prevent scavenging. Collection costs also exist to maintain off-site dumpster, container, and curbside pick-up services (Tchobanoglous et al., 1993). These costs quickly mount and are also cited as one of the driving factors for creating safe biosolids and compost for use in land applications (U.S. EPA, 2011d). Environmental costs include annual monitoring well sampling and leachate disposal which in some instances is classified as a hazardous waste material (U.S. EPA, 2011e). In employing a new solid waste infrastructure, collection costs may be varied if the public is required to sort their waste prior to collection between biodegradable and non-biodegradable materials. In addition, programs to educate the public on the new infrastructure are necessary to successfully implement a widespread change in solid waste services (Robinson et al., 2012).

1.1.5 Public Health Impacts

Public health concerns have always surrounded solid waste, more commonly referred to as trash and garbage, and date back as far as the 1840's when the Chadwick Commission in Great Britain reported a correlation between garbage and incidents of disease (Ross, 2011). This information helped improve quality of life in cities where waste (both liquid and solid) was merely dumped into the street and allowed to wash away with the weather (Burian et al., 2000). The concept of dumping was introduced and resulted in the formation of open waste dumps located away from the city center and followed the "out of sight, out of mind" mentality (Anderson, 1964). This period of time in the mid-19th century also saw the introduction of a centralized sewage collection system for wastewater. Ocean dumping, banned in 1972, was another common disposal practice that evoked additional health and safety concerns as these wastes interfered with aquatic life cycles and clogged commercial waterways (U.S. EPA, 2012). Presently, with the legislation provided by the Clean Water Act (CWA) and the Resource Conservation and Recovery Act (RCRA) current technologies for waste disposal include wastewater treatment facilities, biosolids (treated human waste) recycling, landfilling, and incineration. Biosolids disposal is a promising step forward in sustainable waste management; however, it is often considered controversial with several communities disputing the safety of this practice (Robinson et al., 2012). Incineration has also been implemented successfully and is largely used in the disposal of medical wastes and certain hazardous wastes (U.S. EPA, 2011c).

1.2 OBJECTIVE

Currently, several uncertainties exist in the underlying science behind sustainable waste. For instance, should the aim be a zero waste society and is that attainable? The next step forward is to evaluate existing policy in the United States and in other major governing bodies like the European Commission to determine whether the necessary regulation promoting sustainable alternatives exists.

The primary objective of this research was to evaluate public perceptions of land application of diverted waste streams and identify areas of existing non-hazardous solid waste policy that need to be amended to promote widespread waste reduction in the United States. To accomplish this objective the following was completed as part of this thesis:

1. Analyze and discuss the findings of the biosolids survey issued via telephone to a random sampling of Knox County, Tennessee and Amelia County, Virginia residents.

2. Analyze and discuss the findings of the subsequent animal manure survey issued to random residents located in the same regions as the previous biosolids survey.

3. Evaluate existing public policy concerning non-hazardous solid waste in the United States and propose several policy alternatives to promote waste diversion methods, such as biosolids land application and municipal solid waste composting.

CHAPTER II: PUBLIC ATTITUDES AND RISK PERCEPTION TOWARD LAND APPLICATION OF BIOSOLIDS WITHIN THE SOUTH-EASTERN UNITED STATES

This chapter was originally published by Kevin G. Robinson, Carolyn H., Robinson, Lauren A. Raup-Plummer, and Travis R. Markum:

Robinson, K.G., Robinson, C.H., **Raup, L.A**, and Markum, T.R. (2012). "Public attitudes and risk perception toward land application of biosolids within the south-eastern United States." *Journal of Environmental Management*, 98, 29-36.

While the original study concept, survey design, and survey implementation was provided by Drs. Kevin and Carolyn Robinson, Lauren A. Raup-Plummer provided the statistical analysis and evaluation of the findings, and composed and revised the final published manuscript. Preliminary organization of the data was provided by Travis R. Markum.

2.1. ABSTRACT

A descriptive-correlational study of biosolids recycling was conducted in the south-eastern United States to assess current knowledge, attitudes and risk perceptions of participants in two communities that land apply biosolids as part of their waste management programs. One community, Amelia County VA, has been outspoken against biosolids recycling in the past, whereas the second community, Knoxville, TN region, has voiced few concerns about biosolids recycling. Additionally, gender differences within the entire study population were assessed. A 45-question telephone survey, utilizing a 4-point Likert scale, was developed and administered to 311 randomly selected adults in the two regions. Commonalities identified during the study revealed key risk perceptions by the public regarding biosolids regulations, treatment, and application. Given current perceptions and knowledge, respondents felt that the benefits derived from biosolids recycling do not offset the perceived health and safety risks. However, as distance between application and personal property increased, a decrease in opposition of biosolids reuse became evident for all respondents. Survey

participants were dissatisfied with the level of stakeholder involvement in research and decision-making processes concerning biosolids. The outspoken Amelia County residents perceived greater health risks due to inadequate treatment of biosolids and odorous emissions during the application process than the less engaged Knox Metro respondents. Significant gender differences were observed with sampled females perceiving greater risks to health and safety from biosolids recycling than males. There was also indication that decisions and risks were not sufficiently communicated to the public, leading to respondents being inadequately informed about biosolids land application in both communities. Community-specific outreach programs must address these public risk perceptions and the differences in perception caused by gender and issue awareness to assist solid waste managers in developing and implementing successful biosolids land application systems that are acceptable to the public.

2.2. INTRODUCTION

Unlike pollution created by unnecessary processes or accidental releases, sanitary waste disposal is essential to industrialized society; however, alternatives for biosolids disposal are limited due to enacted regulations that protect other aspects of the environment. In 1990, the United States federal government prohibited ocean dumping of wastes as a result of ocean and shore pollution concerns, which quickly increased the amount of sludge sent to landfills (Logan, 1995). To compound the situation, the quality standards established by the U. S. Clean Water Act for wastewater treatment resulted in additional municipal sludge generation. These pressures, and the on-going recognition of the values of nutrients and organic matter in sewage sludge, led to increased efforts to treat biosolids for recycling to land.

2.2.1. Biosolids Recycling

In 1993, the U. S. Environmental Protection Agency (EPA) promulgated CFR Title 40 Part 503, establishing federal standards for the use or disposal of biosolids. These regulations defined pathogen reduction requirements for municipal sewage sludge resulting in Class A and Class B biosolids standards. Class B biosolids are treated by processes to significantly reduce, but not totally eliminate, pathogen concentrations and therefore require special handling; whereas, Class A biosolids are treated by additional processes to further reduce pathogens to very low concentrations that do not require special handling or other restrictions. Since a variety of pathogens can be found in municipal wastewaters, they may also be present in Class B biosolids (Khuder et al., 2007), particularly enteric viruses due to their resistance to inactivation by heat and high pH (Regli et al., 1991). Furthermore, industrialization activities can introduce chemicals, such as heavy metals and organic toxins, to the waste stream that may accumulate in either Class A or B biosolids. The U. S. EPA has taken the position that the biosolids program is low-risk and low-priority, although there have been concerns voiced about the presence of these pathogenic microorganisms and toxic chemicals in the treated biosolids and the potential risk they pose to public health and safety (Lewis and Gattie, 2002).

In the U.S., the majority of Class B biosolids are land applied, which is viewed as a method of nutrient recovery to enhance the soil properties and increase plant growth (NIOSH, 2006). Although the quality of biosolids has improved with time due to advancement in treatment technologies, some residents around sites where biosolids are applied have complained of odours and alleged illnesses. In some communities, local officials and citizen groups have protested the lack of community control over decisions regarding biosolids, claiming the quality of life has been affected by biosolids land application (National Research Council, 2002). There has been little epidemiological research about impacts on neighbouring residents; however, Khuder et al (2007) examined whether a correlation existed between self-reported health concerns experienced by residents living in Wood County, Ohio (USA), and distance from fields where application of biosolids was permitted. While this study had several limitations due to comparison of limited data provided by postal questionnaires and interviews, findings suggested an increased risk for certain respiratory and gastrointestinal diseases among residents living near biosolids application sites. The findings were in agreement with previous studies performed by Lewis et al (2002), but contradicted research from Dorn et al (1985), which reported no significant increase in risk for neighbouring residents. It should be noted that the management of biosolids, with respect to concentration applied and method of application, can have a significant impact on the risk associated with biosolids land application (Gerba et al., 2002).

2.2.2. Risk Perception

The wastewater and biosolids management profession is continuing to realize the importance of public acceptance and how it can directly influence biosolids recycling. As biosolids have been brought closer to the general public for agricultural benefits, a heightened awareness has resulted surrounding health, safety and environmental impacts. It has been documented that issue awareness plays a key role in the public perception of risk as potential consequences of biosolids land application are now in the forefront of the public mind (Johnson and Scicchitano, 2009). People are beginning to assess for themselves whether or not there is a risk to public health or the environment; therefore, it is important to accurately assess risks as part of the management process (Sjöberg, 2001). Due to the elevated sensitivity of wastewater and biosolids management, public participation in decision-making processes is expected by the involved communities (Monroe, 1990).

The risks associated with biosolids recycling can be viewed and experienced differently, which implies differing opinions on how to both measure and manage those risks (Botterill and Mazur, 2004). While risk is typically defined as a probability of the likelihood of the occurrence and magnitude of the consequence, this rigid characterization fails to include the intuitive aspect that humans utilize to correlate risk to unknown dangers (Slovic, 1999). In reality, risks are *perceived*, and do not correspond with quantifiable frequencies, and therefore are unique to each individual, based on values, education, experiences, phobias, and stake in the outcome (Covello and Sandman, 2001; Slovic, 1999; Spangler, 1984). In general, the public bases a significant part of assessed risk on the variables that are perceived, whereas those with prior technical knowledge heavily weigh risk on the calculable hazards and fail to adequately consider the aspects that cannot be otherwise predicted (Covello and Sandman, 2001).

2.2.3. Risk Management

Risks are a function of perceptions based on differing values; therefore, "risk management decisions must take into account the political, social and ethical, as well as technical, aspects of the policy problem" (Bradbury, 1989). Effective management of biosolids is required to mitigate public health and environmental consequences, and the perception of that management is equally important to provide confidence that land application is a sustainable practice or at least an acceptable risk (Harrison et al., 1999). Part of effectively managing the risk is ensuring that the public is not only aware of the risk but has an understanding of and is in agreement with the risk assessment. Generally, waste management programs have tried to improve acceptability of reuse applications through improved explanations of risk, where lack of knowledge by the population was deemed the primary issue (Nancarrow et al., 2008).

While programs to increase the public's knowledge have helped in educating the public with facts, little attention has been given to addressing the values and beliefs driving the public's perception of risks associated with biosolids recycling. It could be argued that this ineffective approach may have resulted in a decline in public acceptance of biosolids recycling, since the growing frustration and level of uncertainty has not been adequately addressed. Additionally, disagreement among experts confuses the public and damages the credibility of risk assessments, legitimacy of the research and salience for stakeholders and policy developers (Cash et al., 2003). Kim and Mauborgne (2003) found that the process used during research and development is equally as important as the resulting product; therefore, it is important to involve stakeholders from the beginning of any project, not only in the final decision-making process, to increase the level of trust in the community.

Typical risk management strategies involve providing information on key issues to the public to improve awareness; however, the method of delivery must take into account the demographic make-up of the community for the perceived risks to be effectively managed (Slovic, 1999). It has been documented that certain demographics, such as gender, have intrinsic differences in risk perception (Steger and Witt, 1989). Females and males often form significantly different opinions on science and technology based issues (Flynn et al., 1994), with females being typically less receptive to technologies that have perceived risks to health and safety (Slovic, 1999; Steger and Witt, 1989). This gender difference has been documented in several community surveys of environmental issues, and the difference becomes more pronounced in instances where health and safety risks are "linked" to an issue (Bord and O'Connor, 1997). For example, Nancarrow et al. (2008) observed females to be more perceptive of the risks involved with potable wastewater reuse than males while Flynn et al. (1994) found that females surveyed perceived more risks than males on numerous environmental issues including nuclear waste, chemical pollution, and ozone depletion.

Although any understanding of risk perception within a community involves a number of factors, gender differences and issue awareness are two components that should be evaluated when developing an effective management plan for introducing an environmental project to the public. The objective of this study was to assess gender differences and issue awareness impacts regarding public knowledge, attitudes, and perceptions of exposure and risks associated with recycling of biosolids. Results from this project should help, in part, shape management and policy decisions concerning the reuse of biosolids as part of a sustainable resource strategy.

2.3. MATERIALS AND METHODS

The Knoxville, Tennessee (USA) metropolitan area and Amelia County, Virginia (USA) were chosen for participation in an attitudinal telephone survey. These two communities were selected to provide contrasting sample populations regarding involvement in and exposure to the issue of biosolids recycling. In addition, the counties were chosen because they are in the same geographic region, minimizing the effect of regional bias.

According to the U. S. Census Bureau, the population of Knox County during the survey was 396,672, while the population of Amelia County, Virginia was 11,747. The Knoxville metropolitan area is primarily a suburban/urban community that was chosen for study because its residents have voiced few concerns regarding current land application of biosolids in their region. The Amelia County, Virginia population is a rural community which was selected for participation because residents are acutely aware of the biosolids issue through extensive media coverage and have voiced strong public opposition to land application of biosolids. Although biosolids had been land applied to pastures and hay-land in both areas for more than 20 years, Amelia County officials implemented a ban on the land application of biosolids in 1999 based on perceived health, safety and environmental concerns. To the consternation of many county residents, the ban was later overruled by the Supreme Court of Virginia.

Survey development was based on research of literature concerning various environmental issues and an assessment of previously conducted surveys (de Vaus, 1986; Frey and Oishi, 1995; Maurer and Pierce, 1998). The survey was introduced with a statement to capture the respondent's interest as well as provide general information on biosolids (including a brief definition) so that respondents could better understand subsequent questions.

The survey consisted of 45 questions arranged under three categories. The first category was designed to assess general knowledge of biosolids; these questions were developed using publically-available information published by the U.S. EPA concerning biosolids application practices. Respondents were able to choose whether provided statements were true or false. To allow flexibility in answering and to avoid unreliable results, participants were permitted to respond with "Don't Know". The second category focused on attitudes towards biosolids recycling and use. Using the 4-point

Likert scale, each question or statement was followed by the choice of four ranked responses: 1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree; a fifth response, 5 = don't know, was provided as an un-ranked option. Responses of "Don't Know" were removed before determining attitudinal mean response values; however, these values were used in interpreting issue awareness percentages. The third category asked questions to gather sociodemographic information. The factual questions in the survey were asked in the first section in order to keep respondents engaged before attitudinal responses were solicited and demographic questions were posed (de Vaus, 1986).

The survey was conducted via telephone, using random digit dialling (RDD) to generate the two sample populations. The telephone survey was conducted over a two-week period and sampled 311 residents (over 18 years of age), 164 in Amelia County and 147 in the Knoxville area. Personnel affiliated with the Social Science Research Institute (SSRI) at the University of Tennessee conducted the survey. Each survey required about twelve minutes per respondent, and SSRI personnel entered responses directly into the Statistical Package for Social Sciences (SPSS) database for subsequent analysis.

2.4. RESULTS

The majority of the overall sample population was female (55.9%, N=174); the ethnic distribution was primarily Caucasian (88.0%, N=271). The average age of Knoxville area residents was 45.7 while the average age of Amelia County participants was 51.4. A statistical t-test indicated that Knoxville area participants were significantly younger than those in Amelia County (t=-3.223, df=309, p=0.001). The education level differed between the communities as determined by a Chi-Square test (χ^2=18.951, df=4, p=0.001). Approximately 67% of Knoxville residents attended some college or higher, while only 42% of Amelia County residents attended college or graduate school.

Individual ANOVA statistical tests and statistical t-tests were performed to determine the difference between the two surveyed communities. Statements designed to assess the general knowledge of participants about biosolids were answered primarily with less than a 50% correct response rate for each surveyed community (Table 2) although a majority of both communities (56%-68%) were aware that biosolids contain nutrients. Most participants were unaware that, according to the U. S. EPA, health risks from biosolids exposure are less than the health risks associated with animal manure. Respondents were also unaware that the health and safety risks associated with biosolids are higher for children than adults due to increased contact between children and possible exposure pathways such as ingestion (EPA, 1994). Furthermore, the majority of participants were unaware of U. S. EPA regulations regarding pathogen concentrations in biosolids or that land application is the most cost effective method for biosolids disposal in the regions surveyed. Based on the questions posed, the less involved (little opposition or approval) residents in the Knoxville metropolitan area were, in general, somewhat more knowledgeable of biosolids than the issue aware Amelia County community; however, the overall indication is that both communities lacked a firm understanding of biosolids recycling issues.

Assessment of responses to general knowledge statements by gender showed less than a 50% correct response rate for both males and females (Table 3). The majority of both genders incorrectly answered the question concerning whether "exposure to biosolids presents an equal health and safety risk to both children and adults", and females were significantly (p = 0.008) less knowledgeable than males with only 19% responding correctly. While more than half of the surveyed males and females answered the question concerning biosolids contribution to nutrients correctly, males were significantly (p = 0.020) more knowledgeable with 74.5% answering correctly compared to only 52.3% of females. Overall, gender differences pertaining to the knowledge level of biosolids recycling were evident with a consistently larger

Table 2. Distribution of correct responses to knowledge statements by location.

Statement	Correct Response	Knox Metro	Amelia County	*p*-value
According to the EPA, health risks associated with the use of biosolids are greater than health risks associated with the use of animal manure.	False	34.7%	23.3%	0.027*
Exposure to biosolids presents an equal health and safety risk to both children and adults.	False	31.3%	20.1%	0.024*
The EPA currently regulates the levels of disease-causing bacteria in biosolids.	True	49.0%	32.9%	0.004**
Biosolids contribute nutrients, such as nitrogen and phosphorous, to the soil.	True	68.0%	56.7%	0.040*
Land application is currently the cheapest method of biosolids disposal.	True	44.2%	49.4%	0.361
According to the EPA, public health and safety risks from biosolids exposure are low.	True	40.1%	42.1%	0.729

*p<0.05; **p<0.01

Table 3. Distribution of correct responses to knowledge statements by gender.

Statement	Correct Response	Male	Female	*p*-value
According to the EPA, health risks associated with the use of biosolids are greater than health risks associated with the use of animal manure.	False	33.6%	24.7%	0.337
Exposure to biosolids presents an equal health and safety risk to both children and adults.	False	33.6%	19.0%	0.008**
The EPA currently regulates the levels of disease-causing bacteria in biosolids.	True	43.1%	38.5%	0.769
Biosolids contribute nutrients, such as nitrogen and phosphorous, to the soil.	True	74.5%	52.3%	0.020*
Land application is currently the cheapest method of biosolids disposal.	True	55.5%	40.2%	0.328
According to the EPA, public health and safety risks from biosolids exposure are low.	True	48.1%	35.6%	0.059

*p<0.05; **p<0.01

percentage of males providing the correct response when compared to females surveyed.

Attitudes regarding biosolids applications were assessed for each community (Table 4) using a 4-point Likert scale. The averaged response, or mean value, represents the overall attitude of the two survey populations – Knox Metro and Amelia County – for each application. A Likert scale has an equal number of both negative and positive attitudinal responses creating a balanced scale (Cheung and Mooi, 1994); therefore, the mean of these four attitudes, 2.5, represents the neutral point in the scale. Furthermore, a mean response > 2.5 was defined as a positive attitude since Likert values of 3 and 4 represent agreement with a statement, while a mean < 2.5 was defined as a negative attitude since values of 1 and 2 represent disagreement. Issue awareness was determined using Chi-squared analyses. The p-values from these tests represent a comparison between the attitudinal response percentages (rather than "Don't Know" or missing responses) of the studied communities. A community with a significantly larger number of attitudinal responses was considered to be more aware about the issue in question than the other surveyed population.

Overall, applications that would minimize human contact (highway medians/central reservations and hay pastures) were less negative to the surveyed population; however, the Amelia County respondents consistently showed greater opposition to any biosolids reuse application. Amelia County residents were significantly less agreeable to biosolids application in public areas, home flower beds, and home vegetable gardens than the Knox Metro residents. Both communities had negative attitudes towards the applications involving food crops, vegetable gardens, and public areas.

Looking at gender differences, females consistently responded with stronger negative attitudes than males (Table 5). Males had positive attitudes concerning the use of biosolids in highway medians/central reservations and neutral attitudes toward

Table 4. Attitudes regarding biosolids applications by location. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Location	Mean Response	N	Mean *p*-value
Highways medians	Knox	2.87	106	<0.001***
	Amelia	2.33	127	
Pastures where the hay is used to feed animals raised for human consumption	Knox	2.48	107	0.05
	Amelia	2.19	132	
Food crops	Knox	2.18	117	0.002**
	Amelia	1.80	133	
Public areas such as parks, playgrounds, and athletic fields	Knox	2.04	111	0.004**
	Amelia	1.71	141	
Your yard and to flower beds around your home	Knox	2.44	114	0.003**
	Amelia	2.06	144	
Home vegetable gardens	Knox	2.01	111	0.01*
	Amelia	1.71	141	

*p<0.05; **p<0.01; ***p<0.001

their use in pastures where hay is grown for animal feed; however, females expressed negative attitudes toward all land application possibilities presented for biosolids. Females had particularly negative attitudes (Likert responses < 2) for food crop, public area, and home vegetable garden applications. In general, the results indicate that as the distance between application and potential personal contact increase, a decrease in opposition to biosolids reuse occurs.

Attitudes toward perceived public health risks outweighing the benefits derived from biosolids reuse were essentially neutral in both communities (Table 6); however only the Knox Metro residents perceived biosolids as a valuable resource. The issue awareness between these communities regarding the biosolids public health risks and benefits statement was significant ($p < 0.001$) with only 58% of Knox Metro residents providing an attitudinal response (42% “Don’t Know”) compared to 77% of the more issue aware Amelia County residents. Overall, the more engaged Amelia County

Table 5. Attitudes regarding biosolids applications by gender. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Gender	Mean Response	N	Mean *p*-value
Highways medians	Male Female	2.76 2.40	115 118	0.009**
Pastures where the hay is used to feed animals raised for human consumption	Male Female	2.50 2.15	112 127	0.014*
Food crops	Male Female	2.21 1.78	112 138	<0.001***
Public areas such as parks, playgrounds, and athletic fields	Male Female	2.04 1.72	114 144	0.005**
Your yard and to flower beds around your home	Male Female	2.42 2.07	115 143	0.089
Home vegetable gardens	Male Female	1.95 1.75	110 142	0.006**

*p<0.05; **p<0.01; ***p<0.001

Table 6. Attitudes regarding perceived risk (statements 1-3) and risk communication (statements 4-6) of biosolids by location. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Location	Mean Response	N	Mean *p*-value
Biosolids are a valuable resource that should be reused	Knox Amelia	2.72 2.29	93 127	0.003**
The risks to public health outweigh the benefits derived from the reuse of biosolids	Knox Amelia	2.58 2.57	86 127	0.962
Based on my perception of risks and benefits, I would be in favor of the land application of biosolids	Knox Amelia	2.38 2.09	100 137	0.031*
I am satisfied with the procedures used to involve citizens in biosolids <u>decision-making</u>.	Knox Amelia	2.50 2.25	76 118	0.101
Decisions about biosolids management in my community have been made in an <u>open</u> way.	Knox Amelia	2.01 2.45	91 126	0.001**
I feel that I am adequately informed about the potential risks of reusing biosolids.	Knox Amelia	1.97 2.17	122 141	0.105

*p<0.05; **p<0.01

residents were neutral (mean value ≈ 2.45) about the openness of decisions made relating to biosolids issues in their community; although they were significantly more positive when compared to the Knoxville area respondents (mean value ≈ 2.01). Even though the Amelia County respondents were more positive about the openness of decisions made, these residents were more dissatisfied with the level of public involvement. Knox Metro residents were significantly ($p < 0.001$) more likely to respond "Don't Know" (48%) compared to the more engaged Amelia County residents (28%) on the statement concerning public's involvement with biosolids decision-making procedures within the community, indicating that the Amelia County participants were more aware of the current procedures than their counterparts. Both communities agree that they were not adequately informed about the potential risks of biosolids recycling.

Females were not satisfied with biosolids decision-making, the transparency of these decisions, or the risk potential of biosolids reuse (Table 7). Additionally, female participants questioned the value of biosolids reuse and were significantly ($p < 0.001$) against land application based on perceived risks and benefits. Overall, female responses significantly differed from those of males. Male responses were neutral regarding the community involvement on biosolids decision-making and the transparency of those decisions. Males sampled were less negative concerning the adequacy of information regarding potential risks being provided to the public.

Attitudes regarding biosolids' effects on health and safety were examined for each community (Table 8). Both communities showed concern with the health risk associated with the level of pathogens present in the biosolids, yet only the more issue aware Amelia County residents considered the treatment of biosolids at the wastewater treatment plant to be inadequate. In comparing the application of biosolids to animal manure by neighbouring property owners, both communities perceived a greater health risk was associated with the biosolids application. Additionally, participants were clearly

Table 7. Attitudes regarding perceived risk (statements 1-3) and risk communication (statements 4-6) of biosolids by gender. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Gender	Mean Response	N	Mean *p*-value
Biosolids are a valuable resource that should be reused	Male Female	2.71 2.25	106 114	0.002**
The risks to public health outweigh the benefits derived from the reuse of biosolids	Male Female	2.45 2.69	100 113	0.088
Based on my perception of risks and benefits, I would be in favor of the land application of biosolids	Male Female	2.49 1.98	109 128	<0.001***
I am satisfied with the procedures used to involve citizens in biosolids decision-making.	Male Female	2.54 2.17	93 101	0.015*
Decisions about biosolids management in my community have been made in an open way.	Male Female	2.50 2.06	101 116	0.002**
I feel that I am adequately informed about the potential risks of reusing biosolids.	Male Female	2.27 1.93	115 148	0.007**

*p<0.05; **p<0.01; ***p<0.001

Table 8. Attitudes regarding biosolids effect on health and safety by location. Mean response > 2.5 indicates agreement and < 2.5 indicates respondent disagreement.

Statement	Location	Mean Response	N	Mean *p*-value
Biosolids receive adequate treatment at the wastewater treatment plant to protect public health.	Knox Amelia	2.67 2.19	96 107	<0.001***
The presence of disease-causing microorganisms in biosolids, such as bacteria and viruses, are a significant risk to human health.	Knox Amelia	2.98 2.78	124 129	0.115
My family would be at a higher health risk if my neighbors applied biosolids to their land.	Knox Amelia	2.68 2.80	118 148	0.343
My family would be at a higher health risk if my neighbors applied animal manure to their land.	Knox Amelia	2.23 2.14	126 138	0.418
The odor emitted by biosolids presents a risk to my health when breathed.	Knox Amelia	2.23 2.55	115 132	0.018*
I am willing to tolerate the odor emitted during and after land application of biosolids	Knox Amelia	2.01 2.01	112 138	0.965

*p<0.05; ***p<0.001

unwilling (mean values ≈ 2.01) to tolerate odours emitted from the land application of biosolids. Amelia County residents exhibited greater convictions that odour emissions correlated with health risks from the biosolids, which implies that the less engaged Knox Metro community regarded such emissions more as a nuisance than a health concern.

Females perceived a significantly greater health risk associated with pathogens in biosolids than the males ($p < 0.001$), and felt that more treatment was necessary for biosolids at the wastewater treatment plant (Table 9). Male respondents were comfortable with neighbouring property owners applying both biosolids and animal manure to their land, perceiving no health risk to their families. However, females felt that the health risk associated with biosolids application on their neighbours land was problematic compared to the risks associated with animal manure application. Both genders are unwilling to tolerate odour; however, females perceived a health risk from

Table 9. Attitudes regarding biosolids effect on health and safety by gender. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Gender	Mean Response	N	Mean *p*-value
Biosolids receive adequate treatment at the wastewater treatment plant to protect public health.	Male Female	2.54 2.31	93 110	0.104
The presence of disease-causing microorganisms in biosolids, such as bacteria and viruses, are a significant risk to human health.	Male Female	2.60 3.08	108 145	<0.001***
My family would be at a higher health risk if my neighbors applied biosolids to their land.	Male Female	2.39 3.03	118 148	<0.001***
My family would be at a higher health risk if my neighbors applied animal manure to their land.	Male Female	2.08 2.27	122 142	0.103
The odor emitted by biosolids presents a risk to my health when breathed.	Male Female	2.16 2.61	115 132	<0.001***
I am willing to tolerate the odor emitted during and after land application of biosolids	Male Female	2.09 1.95	111 139	0.278

***p<0.001

odour emissions. Overall, females perceived greater health and safety risks from biosolids recycling practices than males.

2.5. DISCUSSION

Most respondents had a general awareness of the benefits of biosolids recycling for soil amendment and nutrient enrichment (68% and 56.7% for surveyed Knox and Amelia communities, respectively), which indicates that advantages to biosolids reuse had been recognized by the majority of the public. However, the female and Amelia County respondents in this survey were less confident in the recyclable qualities of biosolids and were more opposed to the land application of biosolids than the male and Knox Metro participants. Despite the drive that necessitates biosolids recycling practices, the participants were convinced that the benefits do not outweigh the perceived health and safety risks, given their current perceptions and knowledge base. Lack of public knowledge regarding wastewater treatment and the composition of the resulting solids are areas that significantly influence perception. Uncertainties of biosolids risk to human health are low when either the public has no knowledge that the risk exists or when there is accurate and sufficient information to properly evaluate the risk (Machno and Forste, 1997; Logan, 1995). To improve the knowledge base, many municipal facilities use treatment study opportunities to improve the credibility of the operation while contributing to the scientific community; however, for these projects to be considered credible, the public has to be involved from the beginning of the research (Outwater, 1994; Beecher et al, 2004). People are selective in the evidence they will accept and are more likely to see less risk in cases where they see benefits from the activity (Ross and Anderson, 1982).

Study results indicate that as distance between application and personal property increase, thereby reducing the opportunity for personal contact, a decrease in opposition of biosolids reuse became evident, which improves biosolids application acceptability. Results reported by Borden et al (2004) indicated a higher level of support for the use of biosolids in the Las Vegas area, including golf courses and public landscapes, with all locations surveyed receiving at least a 60 percent approval except for the use of biosolids on home vegetable gardens. This indicates that the general acceptability of biosolids application in the south-eastern U.S. may be somewhat lower than that in other regional locations within the U.S. This may be attributed to the availability of animal manure in the south-eastern United States, making it a more accessible alternative in this region.

Both surveyed communities perceived greater health risk associated with exposure to biosolids than animal manure due to the presence of pathogens in the treated waste. This could, in part, be a result of sewage sludge being highly regulated in comparison to animal manure or a result of perceived concerns from media reports that become readily accepted by the public (Tyson, 2002). Due to the lack of accuracy and reliability of information often presented by media sources regarding the application of biosolids, the public is more inclined to reject the application of biosolids when the issue is extensively reported (Lindsay et al., 2000). Increased media coverage of a controversial topic in a community results in increased perceived risks; this effect is commonly referred to as the “outrage factor” (Sandman et al., 1993). This outrage was exemplified by the higher perceived risks of Amelia County residents which was likely due to the negative perceptions created by the county ban on biosolids application in 1999 and the subsequent unpopular Virginia Supreme Court decision to overrule the ban.

Females and Amelia County residents, who perceived that pathogen concentrations in biosolids are a significant risk to human health, attributed the deficiency to inadequate biosolids treatment, which could indicate a lack of confidence in the ability of technology to provide sufficient treatment for public protection. Rodriguez and Peterson (1999) reported that those who express anti-technology attitudes, or do not understand the practice or technology, were more likely to reject the practice, where trust in industry, regulatory agencies and the scientific community play a role in the decision of acceptance or rejection. For these reasons, trust is thought to be one of the most important influences on how people perceive risk and respond to risk communications (Botterill and Mazur, 2004). Furthermore, women have been found to express higher levels of concern towards technology due to a lack of trust in scientific and technological institutions; a lack of trust has also been noted in instances involving local governmental decisions (Davidson and Freudenburg, 1996). In this study, this concern may be attributed to the feminized roles women occupy in this predominantly-conservative region of the U.S.

Odours emitted into the air from improper management of biosolids applications were also perceived to impact health and safety risks by the overall sample population; however, there was indication that the Knox Metro participants and male respondents considered the odours to be a nuisance problem rather than a health risk. On the other hand, female participants and respondents in Amelia County perceived odorous emissions from biosolids as a potential health risk. Even though odours are commonly present at levels far below those considered toxic, they can still play a role in public perception. These perceptions of risk are developed as a result of an invading odour, which in turn leads to the surfacing of other fears and questioning (Tyson, 2002; Shusterman, 1992). The differences in health and safety risk perception by females and outrage-influenced, issue aware populations must be accounted for when developing community-specific outreach programs for biosolids recycling.

The majority of the participants, particularly females, were unaware that regulations had been established for pathogen concentrations in biosolids. This indicates that the public has limited knowledge concerning the regulatory limitations imposed on the process or the state's resolve to enforce those requirements. It also suggests a breakdown in risk communication from policy makers to stakeholders, but since the U.S. EPA has taken the position that the biosolids program is low-risk and low-priority, this concern may be somewhat reasonable. Risk communication is more than explaining risks versus benefits or reflecting current scientific knowledge in lay terms; it involves efforts toward instilling trust. Better communication with those directly affected is needed in order to address individuals' concerns and encourage a more favourable public perception (Tyson, 2002). Moreover, survey participants were unsatisfied with the level of stakeholder involvement in decision-making processes concerning biosolids issues within their respective communities, which indicates that the public has a desire to participate in biosolids management decisions. When asked if health risks outweigh the benefits of biosolids reuse, the overall consensus of the communities was neutral, which strongly suggests that the surveyed population was receptive to evaluating and balancing the risks to public health with the benefits of recycling practices. By allowing an opportunity for stakeholder involvement, it not only reduces conflict over credibility issues from research and eliminates bias among expert opinions; it also provides an avenue for accountability within the community of those that could be affected (Beecher et al., 2004).

2.6. CONCLUSIONS

The findings of this survey can be used to help guide community-specific outreach programs aimed at addressing the following identified perceptions of risks associated with biosolids treatment, regulation, and land application:

- Benefits from biosolids recycling do not offset the perceived health and safety risks, given current perceptions and knowledge base.
- As distance between application and personal property increased, a decrease in opposition of biosolids reuse became evident.
- Female respondents perceived significantly greater health and safety risks from biosolids applications than males.

- Amelia County residents who, in general, were more engaged in biosolids issues within their community, responded with stronger attitudes against biosolids reuse than the less engaged Knox Metro residents.
- A greater health risk was associated with exposure to biosolids than animal manure by all respondents.
- Females and Amelia County residents perceived that biosolids were inadequately treated for land application.
- Odorous emissions resulting from biosolids application activities were perceived to be a health risk to Amelia County residents and females.
- Dissatisfaction with the level of stakeholder involvement in research and decision-making processes concerning biosolids was expressed by all respondents.

Additional studies should investigate sociodemographic aspects relative to perceived risk, and the aspect of trust should be further explored with respect to the way the public responds to perceived risks when information is conveyed by various sources within the community. Limitations of the study were that it was conducted in one region of the country and may not be applicable to other areas. Additionally, cultural groups were not evenly distributed in the region surveyed, and consequently, not equally represented in the study. Control questions in the survey were limited and the order of these statements was not rotated and may be a source of bias. The large percentage of “Don’t Know” responses for some questions/statements, particularly among females and Knox Metro residents, reduces the available sample size for these groups; these differences in sample populations result in increased variability during statistical testing. Some limitations could have been rectified by adding more qualitative response questions to further expound on selected responses to statements.

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CHAPTER III: IMPACT OF ISSUE AWARENESS ON PUBLIC ATTITUDES AND RISK PERCEPTIONS ASSOCIATED WITH ANIMAL MANURE AND BIOSOLIDS LAND APPLICATION PRACTICES

A version of this chapter was originally submitted for publication by Lauren A. Raup-Plummer, Kevin G. Robinson, and Carolyn H., Robinson:

Raup-Plummer, L.A. Robinson, K.G., Robinson, C.H. (2013). "Impact of Issue Awareness on Public Attitudes and Risk Perceptions Associated with Animal Manure and Biosolids Land Application Practices."

While the original study concept, survey design, and survey implementation were provided by Drs. Kevin and Carolyn Robinson, Lauren A. Raup-Plummer organized the survey response data, performed the statistical analysis, evaluated the findings, and composed and revised the final published manuscript.

3.1. ABSTRACT

Two telephone surveys were developed to study knowledge and risk perceptions related to animal manure and biosolids recycling and were administered to randomly selected adults residing within two communities located in the south-eastern United States. The two populations polled were rural Amelia County, Virginia – a community that historically has been outspoken against biosolids land application practices – and metropolitan Knoxville, Tennessee – a community that has voiced few concerns regarding land application of waste materials. The first survey sampled 311 adults on questions involving biosolids; the second survey sampled 303 adults in the same region one year later on similar questions involving animal manure applications. Results from both surveys indicated that a majority of participants incorrectly believed that animal manure is more strictly regulated, more extensively treated, produced in much less quantity, and poses less of a human health risk than biosolids. Overall, respondents were more positive about animal manure than biosolids recycling; however, applications for both materials involving a high potential for direct contact were more

negatively perceived than those with less. Respondent attitudes for both surveys show that issue awareness concerning land application of biosolids is low; these differences in perception caused by lack of issue awareness must be addressed to develop biosolids land application systems that are acceptable to the public. These findings also indicate that gender and location, rather than level of education, contribute significantly to risk perceptions related to biosolids and animal manure land applications.

3.2. INTRODUCTION

In industrialized society, the disposal of animal manure and treated sewage sludge (biosolids) waste streams has become a growing environmental concern. As the population in the United States increases, the volumes of biosolids and animal manure increase concurrently, thus creating a significant stress on existing disposal practices such as landfilling and land application. At present, biosolids disposal alternatives are limited due to enforced regulations that protect other aspects of the environment. Biosolids are subjected to the U.S. Environmental Protection Agency's treatment regulations whereas animal manures are not currently regulated. Both biosolids and animal manure waste materials perform as comparable soil amendments, and the pressures on existing disposal infrastructure has led to increased efforts to improve public acceptance of biosolids recycling. Animal manure is widely accepted as a viable soil amendment, and policy-makers are looking to identify contributing factors to the acceptance of animal manure application practices with the intent to remedy these differences in biosolids perceptions. This study was developed to assess issue awareness impacts regarding public knowledge, attitudes, and perceptions of exposure and risks associated with land application of biosolids and animal manure. Results from this research can be utilized to shape management and policy decisions concerning the reuse of biosolids as part of a sustainable resource strategy.

3.2.1. Land Application Practices

3.2.1.1 Animal Manure

Organic wastes contain high levels of nitrogen and phosphorus which are key compounds in commercial soil amendments (Evans et al., 2004). Land application provides a sustainable pathway for organic waste disposal, and successful implementation of land application has been observed in poultry waste, dairy manure waste, and swine manure waste (Edwards and Daniel, 1992; Vellidis et al., 1996). Animal manure storage and disposal methods are considerably less refined than those involved in biosolids handling due to regulations on sewage sludge collection that are not present in the manure disposal industry (National Research Council, 2002).

Although application of animal manure has been largely accepted by the public as a minimal health risk, a rural community in Vermont expressed concern regarding the environmental impacts of cattle manure disposal practices (Smith et al., 2008). It should be noted that in the study performed by Smith et al. (2008), more concern was voiced regarding manure storage than land application of manure. The residents surveyed expressed public health concerns resulting from animal manure land applications and complained of odorous emissions and the increased presence of disease-causing bacteria within 1.0 mile of the application site. Regardless of these concerns, animal manure applications and the risks associated with these practices are generally accepted by the public as commonplace, especially in agricultural communities that have first-hand experience with livestock (Jamison, 2004; Smith et al., 2008). In many rural communities, when owners of livestock are asked about the associated odour they respond with “smells like money” and accept any associated risks with this observation (Jamison, 2004).

3.2.1.2 Biosolids

Biosolids are defined by the U.S. Environmental Protection Agency (EPA) as organic sewage sludge that has been treated at a municipal wastewater facility (U.S.

EPA, 1995). The EPA issued CFR Title 40 Part 503 in 1993, which established federal standards for the use or disposal of biosolids. Furthermore, these regulations defined standards for two biosolids treatment classes based on extent of pathogen reduction. Class A biosolids are treated to very low pathogens concentrations (less than 1,000 colonies of faecal coliform per gram solids); whereas, Class B biosolids are treated less extensively (concentrations less than 2,000,000 colonies of faecal coliform per gram solids). In the U.S., the majority of biosolids – both Class A and Class B – are land applied, which is viewed as a method of nutrient recovery to enhance the soil properties and increase plant growth (NIOSH, 2006). It should be noted that prior to land application or disposal, federal regulations dictate that representative samples of biosolids are required to undergo analysis for inorganic contaminants, faecal coliform, and enteric viruses to limit public health risks.

The quality of biosolids has improved in recent years due to advancement in wastewater treatment technologies. However, it has been found that the application method of biosolids used plays a significant role in increased health risks, for example highly concentrated biosolids pose more risks than blended forms (Gerba et al., 2002). Several studies have documented that residents located near sites where biosolids were land applied have complained of odours and illnesses (Khuder et al., 2007; Lewis et al., 2002). Findings by Khuder et al. (2007) suggested an increased risk for certain respiratory and gastrointestinal diseases among residents living near biosolids application sites, but similar research from Dorn et al. (1985) reported no significant increase in risk for neighbouring residents.

3.2.2. Risk Perception

Waste management professionals are continuing to realize the importance of public acceptance and how it impacts biosolids recycling efforts. As biosolids have been brought closer to the general public for agricultural benefits, a heightened awareness has resulted surrounding health, safety and environmental impacts. People are beginning to assess for themselves whether or not there is a risk to public health or the environment. Moreover, the risks associated with biosolids recycling can be perceived differently, which results in differing opinions on how to effectively manage the observed risks (Sjöberg, 2001; Botterill and Mazur, 2004).

While risk is mathematically defined as a probability of occurrence multiplied by magnitude of the consequence, this rigid characterization fails to include the intuitive aspect that humans utilize to correlate risk to unknown dangers (Slovic, 1999). In reality, risks are perceived, and therefore are unique to each individual, based on values, education, experiences, phobias, and potential for monetary gain (Covello and Sandman, 2001; Slovic, 1999; Robinson et al., 2012). The general public assesses risk on the health and safety variables that are perceived, whereas those with prior technical knowledge heavily weigh risk on the calculable hazards (Covello and Sandman, 2001).

3.2.3. Risk Management

Effective management of biosolids is required to mitigate public health and environmental consequences. The perception of that management is equally important to provide confidence that land application is a sustainable practice or at least an acceptable risk (Harrison et al., 1999). Effective risk management is achieved by ensuring that the public is not only aware of the risk, but also has an understanding of, and agreement with, the risk assessment. To this end, waste management plans have been designed and implemented to increase the public's knowledge regarding biosolids (Nancarrow et al., 2008). Unfortunately, little attention has been given to addressing the values and beliefs that drive the public's perception of risks associated with biosolids recycling. In some communities, local officials and citizen groups have protested the lack of community control over decisions regarding biosolids. These parties often claim that their quality of life has been negatively affected by biosolids land application (National Research Council, 2002). Evans et al. (2004) proposed that a partnership between the stakeholders and the policy-makers be forged to improve communication, identify gaps in the knowledge of waste recycling, and provide reliable information to provide a foundation for trust between these two populations.

3.2.4. Issue Awareness

Individuals who have been exposed to an environmental issue have had the opportunity to weigh the benefits and consequences of a technology; this awareness of the issue plays a key role in the public perception of risk (Johnson and Scicchitano, 2009; Wallquist et al., 2010). This concept contributes to the differences between animal manure and biosolids perceptions. For instance, animal manure has long been recognized as a valuable soil amendment and is generally accepted by the public (Edwards and Daniel, 1992), while the application of biosolids is a relatively new concept that has been portrayed negatively in the media. In order to develop a collective coping mechanism between animal manure and biosolids, a better understanding of the factors affecting this difference in perception is required (Bauer and Gaskell, 1999; Buijs et al., 2012). Although any understanding of risk perception within a community involves a number of factors, issue awareness is a critical component that should be evaluated when developing an effective management plan for introducing an environmental program to the public.

3.3. MATERIALS AND METHODS

Amelia County, Virginia (USA) and the Knoxville, Tennessee (USA) metropolitan area were chosen to participate in a set of attitudinal telephone surveys. Both surveys were conducted using random digit dialling (RDD) to generate the two sample populations. These two communities were selected to provide contrasting sample populations regarding involvement in and exposure to the issue of biosolids recycling. In addition, the counties were chosen because they are in the same geographic region, minimizing the effect of regional bias.

According to the U. S. Census Bureau, the population of Knox County during the surveys was 396,672, while the population of Amelia County, Virginia was 11,747. The Knoxville metropolitan area (Knox Metro) is primarily a suburban/urban community that was chosen for study because its residents have voiced few concerns regarding current land application of biosolids in their community. The Amelia County, Virginia population is a rural community that has voiced strong public opposition to land application of biosolids and its residents are acutely aware of the biosolids issue through extensive media coverage, thus providing a contrasting community dynamic to the Knoxville residents. Biosolids land application has been implemented in both areas for more than 20 years, with most applications involving pastures and hay-land. However, in 1999 Amelia County officials implemented a ban on the land application of biosolids based on perceived health, safety, and environmental concerns; this ban was later overruled by the Supreme Court of Virginia (Supreme Court of Virginia, 2001).

Two surveys were issued to the Knox Metro and Amelia County communities. One survey pertained to biosolids recycling and the other to animal manure land application practices. The biosolids centric survey consisted of 45 questions arranged under three categories – knowledge, attitude, and sociodemographic information. Both surveys were introduced with statements to capture the respondent's interest as well as provide general information on biosolids (including a brief definition) so that respondents could better understand subsequent questions. The second survey, concerning animal manure applications, also consisted of 45 questions and was arranged in the same form as the biosolids survey. Survey development was based on research of literature concerning various environmental issues and an assessment of previously conducted surveys (de Vaus, 1986; Frey and Oishi, 1995).

The first category of the biosolids survey was designed to assess general knowledge of biosolids; these questions were developed using publically-available information published by the U.S. EPA concerning biosolids application practices. Respondents were asked whether provided statements were true or false. To allow flexibility in answering and to avoid unreliable results, participants were permitted to respond with "Don't Know". The second category focused on attitudes towards biosolids recycling and use. Using the 4-point Likert scale, each question or statement was followed by the choice of four attitudinal responses: 1 = strongly disagree; 2 =

disagree; 3 = agree; 4 = strongly agree; a fifth response, 5 = don't know, was provided as an un-ranked option. Responses of "Don't Know" were removed before determining attitudinal mean response values. The "Don't Know" values were later used in interpreting issue awareness percentages. The third category was designed to gather necessary sociodemographic information. The factual questions in the survey were asked in the first section in order to keep respondents engaged before attitudinal responses were solicited and demographic questions were posed (de Vaus, 1986).

The biosolids telephone survey was conducted over a two-week period and sampled 311 residents (over 18 years of age), 164 in Amelia County and 147 in the Knoxville area. The animal manure telephone survey, implemented approximately one year later, was also conducted over a two-week period and sampled 303 residents (over 18 years of age), 151 in Amelia County and 152 in Knox Metro. Personnel affiliated with the Social Science Research Institute (SSRI) at the University of Tennessee conducted the surveys. Each survey required about twelve minutes per respondent, and SSRI personnel entered responses directly into the IBM Statistical Package for Social Sciences (SPSS) database for subsequent analysis (IBM Corporation, Armonk, New York).

3.4. RESULTS

For the biosolids survey, the majority of the overall sample population was female (55.9%), and the ethnic distribution was primarily Caucasian (88.0%). The average age of Knoxville area residents was 45.7 while the average age of Amelia County participants was 51.4. A statistical t-test indicated that Knoxville area participants were significantly younger than those in Amelia County ($t = -3.223$, $df = 309$, $p = 0.001$). The education level differed between the communities as determined by a Chi-Square test ($\chi^2 = 18.951$, $df = 4$, $p = 0.001$). Approximately 67% of Knoxville residents attended some college or higher, while only 42% of Amelia County residents attended college or graduate school.

Similarly, the majority of the overall sample population for the animal manure survey was female (56.1%), and the ethnic distribution was primarily Caucasian (89.8%). The average age of the Knox Metro respondents was 45.1 while the average age of Amelia County participants was 49.0. A statistical t-test indicated that Knoxville area participants were significantly younger than those in Amelia County (t = -2.084, df = 297, p = 0.038). The education level differed between the communities as determined by a Chi-Square test ($\chi^2 = 7.189$, df = 4, p = 0.126). Approximately 67% of surveyed Knoxville residents attended some college or higher, while only 53% of surveyed Amelia County residents reported some college education. These results indicate that a difference in educational distributions exists between the biosolids and animal manure survey populations.

Statistical t-tests and individual ANOVA tests were performed to determine any significant differences within the surveyed community. General knowledge statements posed to the participants about biosolids were largely answered with less than a 50% correct response rate for each surveyed community, although a majority of both communities were aware that biosolids contain nutrients (Table 10). Knox Metro and Amelia County residents were unaware that, according to the U.S. EPA, the health risks caused by exposure to animal manure are greater than those associated with biosolids. Both communities correctly understood the nutrient value of animal manure. The rural Amelia County community was significantly more knowledgeable than Knox County residents about the existing regulations concerning disease-causing bacteria in animal manure (Amelia = 53%, Knox = 38%, p = 0.044), but less knowledgeable about the regulations concerning disease-causing bacteria in biosolids (Amelia = 33%, Knox = 49.0%, p = 0.004). Both communities incorrectly believed that more human manure (biosolids) is produced than animal manure annually, and that the health risks associated with animal manure use were less than those associated with biosolids. Overall, a stronger understanding of animal manure's nutrient value was depicted by

Table 10. Distribution of correct responses to knowledge statements concerning biosolids and animal manure by location.

Statement	Correct Response	Knox Metro	Amelia County	*p*-value
According to the EPA, health risks associated with the use of biosolids are greater than health risks associated with the use of animal manure.[1]	False	34.7%	23.3%	0.027*
According to the EPA, health risks associated with the use of animal manure are greater than health risks associated with the use of treated human waste.[2]	True	32.5%	27.5%	0.497
The EPA currently regulates the levels of disease-causing bacteria in biosolids.[1]	True	49.0%	32.9%	0.004**
The EPA and USDA currently regulate the levels of disease-causing bacteria in animal manure.[2]	False	38.5%	53.0%	0.044*
Biosolids contribute nutrients, such as nitrogen and phosphorous, to the soil.[1]	True	68.0%	56.7%	0.040*
Animal manure contributes nutrients, such as nitrogen and phosphorous, to the soil.[2]	True	93.0%	97.7%	0.072
More human manure is produced than animal manure in a year.[2]	False	40.7%	41.4%	0.933

*p<0.05; **p<0.01
[1]Data presented from biosolids survey.
[2]Data presented from animal manure survey.

both surveyed populations when compared to similar survey results concerning biosolids.

Looking at gender differences (

Table 11), it becomes apparent that gender differences concerning animal manure knowledge are less significant than those exhibited during the biosolids survey. Both genders were aware that animal manure contributes nutrients to the soil, but males were significantly more knowledgeable than females concerning the nutrient value of biosolids (Males = 74%, Females = 52%, p = 0.020). Both genders incorrectly believed that health risks associated with biosolids are greater than those associated with animal manure, but males were more knowledgeable about the regulations governing levels of disease-causing bacteria in both biosolids and animal manure.

Findings indicated that education was a significant factor for correct response on knowledge-based questions concerning health risks associated with biosolids use (

Table 12). Respondents with a minimum of some college education were more knowledgeable than their less-educated counterparts (High School or Less = 35.2%, Some College or More = 53.8%, p = 0.009), but some disparity exists in the knowledge that biosolids and treated human waste are representative of the same material. Both education groups were knowledgeable about the nutrient value of biosolids and animal manure, with the majority of surveyed individuals in both groups responding correctly.

Attitudes regarding risk perception, risk communication, and health and safety issues for biosolids and animal manure reuse were assessed using a 4-point Likert scale having an equal number of both negative and positive attitudinal responses (Cheung and Mooi, 1994); the mean of these four attitudes, 2.5, represents the neutral point in the scale. For this study a mean response greater than 2.5 was defined as a positive attitude since Likert values of 3 and 4 represent agreement with a statement, while a mean less than 2.5 represents a negative attitude. Issue awareness was determined using Chi-squared (χ^2) analyses. The p-values from these tests represent a comparison

Table 11. Distribution of correct responses to knowledge statements concerning biosolids and animal manure by gender.

Statement	Correct Response	Male	Female	*p*-value
According to the EPA, health risks associated with the use of biosolids are greater than health risks associated with the use of animal manure.[1]	False	33.6%	24.7%	0.337
According to the EPA, health risks associated with the use of animal manure are greater than health risks associated with the use of treated human waste.[2]	True	27.6%	32.1%	0.541
The EPA currently regulates the levels of disease-causing bacteria in biosolids.[1]	True	43.1%	38.5%	0.769
The EPA and USDA currently regulate the levels of disease-causing bacteria in animal manure.[2]	False	53.3%	39.6%	0.057
Biosolids contribute nutrients, such as nitrogen and phosphorous, to the soil.[1]	True	74.5%	52.3%	0.020*
Animal manure contributes nutrients, such as nitrogen and phosphorous, to the soil.[2]	True	95.1%	95.6%	0.869
More human manure is produced than animal manure in a year.[2]	False	40.7%	41.5%	0.920

*$p<0.05$
[1]Data presented from biosolids survey.
[2]Data presented from animal manure survey.

Table 12. Distribution of correct responses to knowledge statements concerning biosolids and animal manure by education.

Statement	Correct Response	High School Degree or Less	Some College or More	*p*-value
According to the EPA, health risks associated with the use of biosolids are greater than health risks associated with the use of animal manure.[1]	False	35.2%	53.8%	0.009**
According to the EPA, health risks associated with the use of animal manure are greater than health risks associated with the use of treated human waste.[2]	True	26.6%	31.5%	0.504
The EPA currently regulates the levels of disease-causing bacteria in biosolids.[1]	True	67.9%	71.7%	0.626
The EPA and USDA currently regulate the levels of disease-causing bacteria in animal manure.[2]	False	40.8%	50.0%	0.213
Biosolids contribute nutrients, such as nitrogen and phosphorous, to the soil.[1]	True	84.1%	88.1%	0.385
Animal manure contributes nutrients, such as nitrogen and phosphorous, to the soil.[2]	True	96.9%	94.4%	0.320
More human manure is produced than animal manure in a year.[2]	False	33.3%	45.5%	0.128

**$p<0.01$

[1]Data presented from biosolids survey.

[2]Data presented from animal manure survey.

between the attitudinal response percentages (rather than “Don’t Know” or missing responses) of the studied communities. A community with a significantly larger number of attitudinal responses was considered to be more aware about the issue in question than the other surveyed population, in that they felt informed enough to provide a response.

Perceived risks were assessed for biosolids recycling and animal manure reuse applications in both surveys (Table 13). Both communities perceived animal manure as a valuable resource, only Knox Metro residents indicated that they perceived biosolids as a valuable resource. This was significantly different ($p = 0.003$) than Amelia County’s attitude towards biosolids. Furthermore, both communities were neutral concerning whether the risks of biosolids outweighed the benefits derived from recycling practices. However, the responding population for Knox Metro was significantly lower than that for Amelia County concerning whether the risks outweighed the benefits related to biosolids reuse ($p < 0.001$). This indicates that the Amelia County respondents were more aware of the biosolids land application issue than their counterparts. Amelia County residents consistently favoured animal manure applications over biosolids; notably, when asked whether they favoured land application of biosolids they responded negatively (mean value ≈ 2.09) and when asked the same question concerning animal manure they responded positively (mean value ≈ 3.02). Knox Metro residents consistently expressed similar attitudes between the risks and benefits associated with biosolids and animal manure land application; however, Knox Metro residents still preferred animal manure applications (mean value ≈ 2.87) over biosolids applications (mean value ≈ 2.38).

For gender, perceived risks of biosolids and animal manure varied greatly between males and females (Table 14). Significantly, males responded in agreement that biosolids are a valuable resource (mean value ≈ 2.71), while females responded in disagreement (mean value ≈ 2.25). Attitudes towards animal manure’s value and reuse also indicated a significant difference ($p = 0.007$). Although, both males and females

Table 13. Attitudes regarding perceived risk of biosolids and animal manure by location. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Location	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
Biosolids are a valuable resource that should be reused.[1]	Knox Amelia	2.72 2.29	93 127	0.003**	63.3% 77.4%	0.006**
Animal manure is a valuable resource that should be reused.[2]	Knox Amelia	3.01 3.13	128 127	0.311	84.2% 84.1%	0.980
The risks to public health outweigh the benefits derived from the reuse of biosolids.[1]	Knox Amelia	2.58 2.57	86 127	0.962	58.5% 77.4%	<0.001***
The risks to public health outweigh the benefits derived from the reuse of animal manure.[2]	Knox Amelia	2.53 2.26	95 107	0.078	62.5% 70.9%	0.123
Based on my perception of risks and benefits, I would be in favor of the land application of biosolids.[1]	Knox Amelia	2.38 2.09	100 137	0.031*	68.0% 83.5%	0.001**
Based on my perception of risks and benefits, I would be in favor of the land application of animal manure.[2]	Knox Amelia	2.87 3.02	117 127	0.227	77.0% 84.1%	0.117

*p<0.05; **p<0.01; ***p<0.001
[1]Data presented from biosolids survey.
[2]Data presented from animal manure survey.

Table 14. Attitudes regarding perceived risk of biosolids and animal manure by gender. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Gender	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
Biosolids are a valuable resource that should be reused.[1]	Male	2.71	106	0.002**	77.4%	0.023*
	Female	2.25	114		65.5%	
Animal manure is a valuable resource that should be reused.[2]	Male	3.23	123	0.007**	92.5%	<0.001***
	Female	2.92	132		77.6%	
The risks to public health outweigh the benefits derived from the reuse of biosolids.[1]	Male	2.45	100	0.088	73.0%	0.129
	Female	2.69	113		64.9%	
The risks to public health outweigh the benefits derived from the reuse of animal manure.[2]	Male	2.24	98	0.067	73.7%	0.022*
	Female	2.52	104		61.2%	
Based on my perception of risks and benefits, I would be in favor of the land application of biosolids.[1]	Male	2.49	109	<0.001***	79.6%	0.217
	Female	1.98	128		73.6%	
Based on my perception of risks and benefits, I would be in favor of the land application of animal manure.[2]	Male	3.15	115	0.003**	86.5%	0.021*
	Female	2.78	129		75.9%	

*p<0.05; **p<0.01; ***p<0.001

[1]Data presented from biosolids survey.

[2]Data presented from animal manure survey.

agreed that animal manure is a valuable resource. Similar findings were observed in questions assessing whether a respondent would be in favour of biosolids applications, with males being neutral about the reuse of biosolids and females responding negatively (mean values ≈ 2.49 and ≈ 1.98, respectively). A greater percentage of the male population responded to animal manure centred statements when compared to the females; this indicates a difference in issue awareness. Notably, 92% of males responded to the question concerning animal manure's resource value compared to only 77% of females responding ($p < 0.001$). This difference was not as prominent in the biosolids centric questions likely indicating that both genders were equally aware of the perceived risks of biosolids reuse despite differences in attitudinal response.

Two populations – "High School Degree or Less" and "Some College or More" – were reviewed to determine whether perceived risks were influenced by level of education (Table 15). Respondents having a "High School Degree or Less" responded negatively concerning the value of biosolids as a resource (mean value ≈ 2.34), but positively when the same statement was posed for animal manure (mean value ≈ 3.06). Respondents having more education had neutral to positive attitudes (mean value ≈ 2.58) towards biosolids value as a resource and also exhibited a neutral attitude (mean value ≈ 2.53) on whether the risks outweighed the benefits for biosolids reuse. Both populations were in favour of animal manure land application practices despite any perceived risks, but responded negatively to similar statements concerning biosolids reuse. No significant differences in issue awareness were observed regarding perceived risks of biosolids and animal manure, and perceived risks of biosolids and animal manure did not appear to be significantly influenced by differing levels of education.

Risk communication questions (Table 16) indicated that both the Knox Metro and Amelia County communities felt more informed about the risks associated with animal manure than those associated with biosolids. Robinson et al. (2012) found that Knox Metro residents were significantly ($p < 0.001$) more likely to respond "Don't Know" (48%) compared to the more engaged Amelia County residents (28%) on the statement

Table 15. Attitudes regarding perceived risk of biosolids and animal manure by level of education. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Level of Education	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
Biosolids are a valuable resource that should be reused.[1]	High School Degree or Less	2.34	102	0.095	72.3%	0.572
	Some College or More	2.58	118		69.4%	
Animal manure is a valuable resource that should be reused.[2]	High School Degree or Less	3.06	106	0.791	86.9%	0.277
	Some College or More	3.09	148		82.2%	
The risks to public health outweigh the benefits derived from the reuse of biosolids.[1]	High School Degree or Less	2.64	99	0.437	70.2%	0.551
	Some College or More	2.53	114		67.1%	
The risks to public health outweigh the benefits derived from the reuse of animal manure.[2]	High School Degree or Less	2.37	82	0.765	67.2%	0.842
	Some College or More	2.41	119		66.1%	
Based on my perception of risks and benefits, I would be in favor of the land application of biosolids.[1]	High School Degree or Less	2.05	106	0.026*	75.2%	0.698
	Some College or More	2.34	131		77.1%	
Based on my perception of risks and benefits, I would be in favor of the land application of animal manure.[2]	High School Degree or Less	3.01	103	0.486	84.4%	0.153
	Some College or More	2.92	140		77.8%	

*p<0.05
[1]Data presented from biosolids survey.
[2]Data presented from animal manure survey.

Table 16. Attitudes regarding risk communication concerning biosolids and animal manure land application by location. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Location	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
I am satisfied with the procedures used to involve citizens in biosolids decision-making.[1]	Knox Amelia	2.50 2.25	76 118	0.101	51.7% 72.0%	<0.001***
I am satisfied with the procedures used to involve citizens in animal manure decision-making.[2]	Knox Amelia	2.47 2.83	90 105	0.011*	59.2% 69.5%	0.061
Decisions about biosolids management in my community have been made in an open way.[1]	Knox Amelia	2.01 2.45	91 126	0.001**	61.9% 76.8%	0.004**
Decisions about animal manure management in my community have been made in an open way.[2]	Knox Amelia	2.22 2.80	88 111	<0.001***	57.9% 73.5%	0.004**
I feel that I am adequately informed about the potential risks of reusing biosolids.[1]	Knox Amelia	1.97 2.17	122 141	0.105	83.0% 86.0%	0.467
I feel that I am adequately informed about the potential risks of reusing animal manure.[2]	Knox Amelia	2.19 2.70	120 125	<0.001***	78.9% 82.8%	0.396

*p<0.05; **p<0.01; ***p<0.001
[1]Data presented from biosolids survey.
[2]Data presented from animal manure survey.

concerning the public's involvement with biosolids decision-making procedures within the community, thus indicating that the Amelia County participants were more aware of the current procedures than their counterparts. Amelia County residents expressed significantly more positive attitudes ($p = 0.011$) towards their involvement in animal manure decision-making than the more neutral Knox Metro population. While Knox Metro residents responded neutrally concerning decision-making procedures, these residents expressed disagreement with statements regarding whether the decisions about biosolids and animal manure management in their community were made in an open way (mean values ≈ 2.01 and ≈ 2.22, respectively). Knox Metro and Amelia County respondents agree that they were not adequately informed about the potential risks of biosolids recycling.

With regards to risk communication practices, females felt significantly less satisfied with the existing decision-making procedures used to involve the citizens in biosolids and animal manure management than their male counterparts (

). Females responded negatively on citizen involvement and openness associated with biosolids management practices (mean value ≈ 2.17 and 2.06, respectively) and neutrally on parallel statements concerning animal manure (mean value ≈ 2.49 and 2.49, respectively). These attitudes were significantly different from those exhibited by the male population, who responded neutrally on biosolids statements regarding citizen involvement (mean value ≈ 2.54) and openness of decision-making (mean value ≈ 2.50) and in agreement with parallel corresponding statements concerning animal manure management. Both males and females felt inadequately informed about the potential risks associated with biosolids reuse.

Level of education did not greatly affect attitudes regarding risk communication of biosolids and animal manure land applications (Table 18). The "High School Degree or Less" and the "Some College or More" populations were both dissatisfied with the procedures used to involve citizens in biosolids decision making, but both populations

Table 17. Attitudes regarding risk communication concerning biosolids and animal manure land application by gender. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Gender	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
I am satisfied with the procedures used to involve citizens in biosolids decision-making.[1]	Male Female	2.54 2.17	93 101	0.015*	67.9% 58.0%	0.075
I am satisfied with the procedures used to involve citizens in animal manure decision-making.[2]	Male Female	2.83 2.49	96 99	0.018*	72.2% 58.2%	0.012*
Decisions about biosolids management in my community have been made in an open way.[1]	Male Female	2.50 2.06	101 116	0.002**	73.7% 66.7%	0.179
Decisions about animal manure management in my community have been made in an open way.[2]	Male Female	2.61 2.49	94 105	0.403	70.7% 61.8%	0.105
I feel that I am adequately informed about the potential risks of reusing biosolids.[1]	Male Female	2.27 1.93	115 148	0.007**	83.9% 85.1%	0.787
I feel that I am adequately informed about the potential risks of reusing animal manure.[2]	Male Female	2.58 2.35	113 132	0.093	85.0% 77.6%	0.108

*p<0.05; **p<0.01

[1]Data presented from biosolids survey.

[2]Data presented from animal manure survey.

Table 18. Attitudes regarding risk communication concerning biosolids and animal manure land application by level of education. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Level of Education	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
I am satisfied with the procedures used to involve citizens in biosolids decision-making.[1]	High School Degree or Less Some College or More	2.41 2.29	90 104	0.420	63.8% 61.2%	0.631
I am satisfied with the procedures used to involve citizens in animal manure decision-making.[2]	High School Degree or Less Some College or More	2.66 2.68	82 112	0.891	67.2% 62.2%	0.375
Decisions about biosolids management in my community have been made in an open way.[1]	High School Degree or Less Some College or More	2.41 2.16	96 121	0.078	68.1% 71.2%	0.555
Decisions about animal manure management in my community have been made in an open way.[2]	High School Degree or Less Some College or More	2.56 2.54	84 114	0.915	68.9% 63.3%	0.322
I feel that I am adequately informed about the potential risks of reusing biosolids.[1]	High School Degree or Less Some College or More	2.17 2.00	118 145	0.177	83.7% 85.3%	0.696
I feel that I am adequately informed about the potential risks of reusing animal manure.[2]	High School Degree or Less Some College or More	2.57 2.39	95 149	0.199	77.9% 82.8%	0.288

[1]Data presented from biosolids survey.
[2]Data presented from animal manure survey.

responded that they were satisfied with the procedures used for animal manure decision-making. Respondents felt that they weren't adequately informed about the potential risks of biosolids reuse regardless of additional educational experience.

Attitudes regarding biosolids' effects on health and safety were examined for each community (

Table 19). Only Amelia County residents considered the treatment of biosolids at the wastewater treatment plant to be inadequate (mean value ≈2.19). However, both communities believed that animal manure is treated adequately at the farm site to protect public health. Knox Metro residents perceived equal risks to human health from odour emitted by animal manure and biosolids, while Amelia County respondents exhibited significantly greater convictions that odour emissions correlated with health risks from the biosolids ($p = 0.018$). Both surveys posed questions concerning the application of biosolids by neighbouring property owners, with one survey utilizing the term "biosolids" and the other "treated human waste." Both communities perceived a greater health risk was associated with the treated human waste over biosolids indicating that the population does not fully understand biosolids reuse and that a gap in technical knowledge exists. It is important to note that the biosolids terminology has reduced perceived risks in both communities.

Health and safety responses were examined for both gender populations (

Table 20). Awareness of health and safety topics was not considered significant; however, perceived health risks were consistently higher for females than males.

Notably, females expressed agreement with the statement addressing whether their family would be at a higher health risk if neighbours applied biosolids to their land. Females were not dissuaded by the change in terminology between biosolids and treated human waste, but males responded that less health risk was associated with land application of biosolids (mean value ≈ 2.39) than treated human waste (mean value ≈ 2.92). Additionally, females felt that odorous emissions resulting from biosolids application activities were a health risk, while males disagreed.

Table 19. Attitudes regarding health and safety of biosolids and animal manure by location. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Location	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
Biosolids receive adequate treatment at the wastewater treatment plant to protect public health.[1]	Knox Amelia	2.67 2.19	96 107	<0.001***	65.3% 65.2%	0.991
Animal manure receives adequate treatment to protect public health at the farm site where it is generated.[2]	Knox Amelia	2.57 2.88	98 109	0.022*	64.5% 72.2%	0.149
My family would be at a higher health risk if my neighbors applied biosolids to their land.[1]	Knox Amelia	2.68 2.80	118 148	0.343	80.3% 90.2%	0.013*
My family would be at a higher health risk if my neighbors applied treated human waste to their land.[2]	Knox Amelia	3.11 2.92	129 133	0.148	84.9% 88.1%	0.414
The odor emitted by biosolids presents a risk to my health when breathed.[1]	Knox Amelia	2.23 2.55	115 132	0.018*	78.2% 80.5%	0.623
The odor emitted by animal manure presents a risk to my health when breathed.[2]	Knox Amelia	2.24 2.02	118 134	0.090	77.6% 88.7%	0.010*

*p<0.05; ***p<0.001

[1]Data presented from biosolids survey.

[2]Data presented from animal manure survey.

Table 20. Attitudes regarding health and safety of biosolids and animal manure by gender. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Gender	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
Biosolids receive adequate treatment at the wastewater treatment plant to protect public health.[1]	Male Female	2.54 2.31	93 110	0.104	67.9% 63.2%	0.391
Animal manure receives adequate treatment to protect public health at the farm site where it is generated.[2]	Male Female	2.84 2.64	98 109	0.153	73.7% 64.1%	0.076
My family would be at a higher health risk if my neighbors applied biosolids to their land.[1]	Male Female	2.39 3.03	118 148	<0.001***	86.1% 85.1%	0.789
My family would be at a higher health risk if my neighbors applied treated human waste to their land.[2]	Male Female	2.92 3.09	116 146	0.196	87.2% 85.9%	0.736
The odor emitted by biosolids presents a risk to my health when breathed.[1]	Male Female	2.16 2.61	115 132	<0.001***	83.9% 75.9%	0.080
The odor emitted by animal manure presents a risk to my health when breathed.[2]	Male Female	2.00 2.33	116 136	0.071	87.2% 80.0%	0.096

*p<0.05; ***p<0.001

[1]Data presented from biosolids survey.

[2]Data presented from animal manure survey.

Health and safety risk perceptions made by both education levels favoured animal manure applications over biosolids (Table 21). The less educated respondents perceived more risks to odorous emissions from biosolids than the respondents having a minimum of some college education ($p = 0.026$). Both education groups agreed that their families would be at a higher health risk if their neighbours applied biosolids to their land. This attitudinal response was more pronounced for the analogous statement concerning treated human waste. Differences in awareness were not significant.

3.5. DISCUSSION

The comparison of findings from the biosolids and animal manure surveys provides insight into a marked difference in risk perceptions regarding these materials. Compared responses indicate that issue awareness is a contributing factor for the majority of the public despite sociodemographic differences. By drawing careful parallels between the generally accepted risks of animal manure applications and the lesser accepted, but similar, risks associated with biosolids applications, collective coping mechanisms may be used to enhance favourable issue awareness of biosolids recycling. This collective coping mechanism utilizes the public's perception of an existing and accepted practice, in this case animal manure land application, to reduce the risks posed by the more "threatening" biosolids (Bauer and Gaskell, 1999; Buijs et al., 2012). Additionally, further risk management efforts will likely be required to address the risk management minutiae for perception differences corresponding to location, gender, and level of education.

The majority of respondents understood that animal manure contributed nitrogen and phosphorous to the soil, but a smaller portion of the surveyed participants were knowledgeable on the nutrient contributions of biosolids. Residents in both communities felt inadequately informed about the potential risks associated with biosolids reuse and responded that they were not in favour of land application of

Table 21. Attitudes regarding health and safety of biosolids and animal manure by level of education. Mean response > 2.5 indicates agreement with the statement, < 2.5 indicates disagreement.

Statement	Level of Education	Mean Response	N	Mean *p*-value	Population Responding	Response *p*-value
Biosolids receive adequate treatment at the wastewater treatment plant to protect public health.[1]	High School Degree or Less	2.38	96	0.603	68.1%	0.343
	Some College or More	2.45	107		62.9%	
Animal manure receives adequate treatment to protect public health at the farm site where it is generated.[2]	High School Degree or Less	2.74	86	0.985	70.5%	0.484
	Some College or More	2.74	112		66.7%	
My family would be at a higher health risk if my neighbors applied biosolids to their land.[1]	High School Degree or Less	2.72	125	0.689	88.7%	0.154
	Some College or More	2.77	141		82.9%	
My family would be at a higher health risk if my neighbors applied treated human waste to their land.[2]	High School Degree or Less	3.10	107	0.288	87.7%	0.593
	Some College or More	2.97	154		85.6%	
The odor emitted by biosolids presents a risk to my health when breathed.[1]	High School Degree or Less	2.56	112	0.026*	79.4%	0.996
	Some College or More	2.27	135		79.4%	
The odor emitted by animal manure presents a risk to my health when breathed.[2]	High School Degree or Less	2.20	100	0.348	83.3%	0.662
	Some College or More	2.08	151		83.9%	

*p<0.05; ***p<0.001

[1]Data presented from biosolids survey.

[2]Data presented from animal manure survey.

biosolids based on their current perceptions. Knox County residents responded that they felt inadequately informed about the risks associated with reusing animal manure, but they were in favour of land application of animal manure despite this lack of information. This can, in part, be contributed to the Knox County residents having greater awareness concerning the value of animal manure as a resource (84% responding) over the value of biosolids (63% responding). Location was considered a significant factor for biosolids questions as Amelia County residents do not feel that biosolids are a valuable resource. These findings further expound those discussed by Robinson et al. (2012) which found that the increased media coverage during the county ban on biosolids application resulted in higher perceived risks by Amelia County respondents. This effect is commonly referred to as the “outrage factor” and was not present in the Amelia County responses concerning animal manure applications (Sandman et al., 1993).

Gender differences were present in responses for statements concerning both biosolids and animal manure applications. Females perceived greater health risks than males for both biosolids and animal manure reuse applications. Males considered both animal manure and biosolids as valuable resources, but animal manure applications were deemed more favourable based on risk perceptions. Both genders felt significantly uninformed about the potential risks associated with biosolids reuse, but females were less satisfied with current decision-making procedures involving the public. This finding is in agreement with previous studies that found that women are lest trusting of local governmental decisions and technology than men (Davidson and Freudenburg, 1996). Furthermore, it has been postulated that women exhibit a more cautious, protective stance towards environmental issues due to an innate “motherhood mentality” that results in higher perceived health risks (Momsen, 2000). This mentality may be more prominent in the studied region due to the more conservative culture present in the south-eastern United States.

Differences in perceived risks by level of education were less pronounced than those observed for location and gender. Overall, the less educated respondents responded more negatively than the more educated survey participants on biosolids reuse statements; however, the differences in perceived risks between the two groups were largely statistically insignificant. More educated respondents were dissatisfied with current decision-making procedures involving biosolids and felt that the decisions made in their communities were not made in an open way. Previous studies have found that the more educated population desire increased citizen involvement in decision-making procedures regarding environmental issues (Pilusek et al. 1987). The results of this study indicate that knowledge imparted by increased level of education may not heavily influence risk perceptions concerning biosolids land application. Steel et al. (1990) observed that level of education was consistently not a factor in environmental and technological risk perception. Due to the connection between land application practices and the often less conventionally educated farming community, this effect on risk perception may be more strongly exemplified.

3.6. CONCLUSIONS

By improving awareness of the issue and providing the public with references to better known amendments, such as animal manure, the overall perceived risks of biosolids should decrease with increased acceptance of perceived benefits. The findings of this comparative study can be used to help create a risk management plan using collective coping mechanisms that address the following differences in perception between biosolids and animal manure:

- Both communities indicated that they were more adequately informed about the risks associated with animal manure than those associated with biosolids.
- Greater health risks were associated with exposure to biosolids than animal manure by all respondents.

- Gender and location, rather than level of education, contribute significantly to risk perceptions related to biosolids and animal manure land applications.
- The term "biosolids" has improved perceived risks associated with treated human waste materials.

Limitations of the study were that the surveys were conducted in one region of the country and the findings presented here may not be applicable to other areas. The studied regions did not contain an even distribution of cultural groups, and consequently, not all cultural groups were equally represented in the survey findings. The survey contained a limited number of control questions and the order of these statements was not rotated and may be a source of bias. The large percentage of "Don't Know" responses for some questions/statements reduces the available sample size for these groups; these differences in sample populations result in increased variability during statistical testing. In addition to limitations due to survey construction, variability may be introduced due to the difference in education demographic data between each survey population. The findings have indicated that other demographic factors account for the majority of response variation. Some limitations could have been rectified by adding more qualitative response questions to further expound on selected responses to statements.

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CHAPTER VI: PROPOSED AMENDMENTS TO SOLID WASTE POLICY

This chapter has been included to fulfill the requirements of the Environmental Policy Minor issued under the University of Tennessee's Department of Political Science. The findings presented here are based on the interpretation of current legislature and projected demands on existing solid waste infrastructure due to continued population growth.

4.1. ABSTRACT

Municipal solid waste is an area of critical interest for the U.S. Environmental Protection Agency (U.S. EPA), and this is largely due to the non-sustainable nature of existing land disposal/landfilling practices and policies (TDEC, 2008). Estimates made in 1996 indicate that there were 3581 active landfills in the United States; however, in 2010 the total number of landfills in the United States was only 1908. This number continues to decline as older facilities reach design capacity. Furthermore, new facilities are limited due to siting difficulties created by the extensive regulations governing landfill construction, and also in part by negative receptions by the general populous (U.S. EPA, 1996; U.S. EPA, 2010). With fewer landfills being opened and operated, the reduction of landfill volume has become a significant concern in solid waste management. At present, the management of solid waste falls under the ruling of the Resource Conservation and Recovery Act (RCRA), but RCRA focuses on waste classification and landfilling guidelines rather than pre-treatment methods and other more sustainable alternatives. Despite recent efforts to promote "Reduce, Reuse, Recycle", recycling programs remain voluntary, and the number of MSW pre-treatment facilities remains small, with only 115 waste-to-energy incineration plants and 11 composting facilities being in operation during 2010. The existing regulation is not sufficient for a sustainable future, and municipal solid waste treatment practices will need to be modified to meet future demands.

4.2. EXISTING POLICY AND REGULATIONS

In 1970 the U.S. Environmental Protection Agency (U.S. EPA) was formed under the Nixon Administration, and environmental policy was ratified to promote environmentally acceptable waste management techniques (U.S. EPA, 2012a). The emergence of public awareness concerning environmental contamination required the federal government to establish standards and regulations to protect air quality, water quality, soil quality, and public health. For solid waste management programs, current protocols are governed by the regulations described in the Clean Air Act of 1963 (later amended in 1970, 1977, and 1990), the Clean Water Act of 1972 (notable amendments occurred in 1977 and 1987), the Marine Protection, Research, and Sanctuaries Act of 1972, and the Resource Conservation and Recovery Act of 1976 (amended in 1984 to include Underground Storage Tank regulations) (U.S. EPA, 2011b; U.S. EPA, 2011c; U.S. EPA, 2012b; U.S. EPA, 2012c). The influences the aforementioned legislature has imposed on solid waste management are explained in detail in the following paragraphs.

As part of the U.S. EPA's original mission, the Clean Air Act (CAA) was sanctioned to promote air quality standards and management strategies. The CAA was initially passed in 1963; however, the amendments in 1970, 1977, and 1990 established a comprehensive protocol for air quality standards and control methods (U.S. EPA, 2012c). Unlike the Clean Water Act and the Resource Conservation and Recovery Act, both of which are found in the Title 40 – Protection of Environment – section of the U.S. Code of Federal Regulations (U.S. *CFR*), the CAA is officially part of Title 42, Chapter 85 legislation governing Public Health; furthermore, the act itself consists of five titles: Air Pollution Prevention and Control, Emission Standards for Moving Sources, General, Acid Deposition Control, Permits and Stratospheric Ozone Protection (40 *CFR* 85, 1990a; U.S. EPA, 2012c). Provisions of the CAA are mentioned in Title 40 Subchapter C, Part 50; however, it primarily concerns the control of air pollution from mobile sources (40 *CFR* 50, 1990b). The CAA is significant to virtually all sectors of U.S. infrastructure due to the implementation of the National Ambient Air Quality Standards (NAAQS) which created air pollution standards for six principal pollutants – carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide (U.S. EPA, 2011d). This legislation is applicable to solid waste management due to the regulations on particulate matter, lead, and other toxic emissions that may be released from incinerating commercial, municipal, and industrial solid wastes (U.S. EPA, 2012d).

With the emergence of public health protection measures in the 1970s, clean surface waters became a focal issue in environmental policy. After much deliberation, the Clean Water Act (CWA) was passed in 1972 and was authorized to monitor and protect the U.S. water supply from toxic contaminants (U.S. EPA, 2011b). It should be noted that the CWA does not specifically regulate groundwater bodies (aquifers) or federal drinking water standards (U.S. EPA, 2011b; U.S. EPA, 2011e). Federal drinking water standards were established by the Safe Drinking Water Act and are found in *CFR* Title 40 Subchapter D Parts 141-143 (40 *CFR* 141, 1996b). The CWA is of particular interest to solid waste management as the leachate collected at landfill must be treated either on-site or at a permitted municipal wastewater facility prior to discharge. The legislation established by the CWA introduced the National Pollutant Discharge Elimination System (NPDES), which is a permitting program that regulates point source emissions into U.S. waters (U.S. EPA, 2009). Therefore, these wastewater treatment plants, in addition to landfills that treat their leachate on-site, must be permitted through the NPDES program due to the ultimate discharge of treated water into a nearby body (U.S. EPA, 2011b).

In the U.S. Code of Federal Regulations, ocean dumping is discussed prior to the solid waste legislation as it pertains to the protection of marine environments. Title 40 *CFR* 220-238 discusses the regulations imposed by the Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972, more commonly known as the Ocean Dumping Act. In 1988 the MPRSA was amended to ban the dumping of municipal and industrial solid waste into the oceans to protect aquatic life, promote human health, and reduce marine debris (40 *CFR 220*, 2002). This ban limited the options for solid waste disposal and increased the volume of waste being placed on the nation's landfills (Robinson et al., 2012).

Of the existing regulation being implemented in the United States, the Resource Conservation and Recovery Act (RCRA) is the most applicable to solid waste management and technologies. Under RCRA, solid waste is classed into one of the following four categories: Municipal Solid Waste (MSW), Construction and Demolition (C&D) waste, Industrial Solid Waste (ISW), and Hazardous Solid Waste (HSW) (40 *CFR* 239-258, 1996a). Specific guidelines governing MSW disposal can be found in RCRA Subtitle D, typically referred to as Title 40 *CFR* 239-258, and outlined disposal methods include options such as combustion for energy recovery (incineration) and landfilling (40 *CFR* 239-258, 1996a). This act covers hazardous and non-hazardous waste landfills, incineration, and land application guidelines. One of the most disputed sections of RCRA involves treated human waste (biosolids) disposal. In 1993, the EPA issued the U.S. *CFR* Title 40 Part 503 in 1993, which established federal standards for the use or disposal of biosolids. Currently, solid waste management programs are being employed to improve public perception of the biosolids land application regulations; however, due to negative risk perceptions regarding biosolids this program is not considered to be a complete success at present (Robinson et al., 2012). Similar issues have been encountered with the incineration program.

Regulations in comparable governments, such as the European Union, have addressed the need for a more sustainable solid waste system. The Landfill Directive of 1999 (1999/31/EC) mandates that all member states in the European Union will reduce their biodegradable waste stream (based on 1995 estimates) by 35% before 2016 (European Commission, 1999; European Commission, 2010). Based on the existing United States solid waste legislation, amendments to the Resource Conservation and Recovery Act are necessary to maintain the sustainable future being advocated by the Obama administration (Office of the Press Secretary, 2009). The successful execution of these changes will require collaboration between the U.S. EPA, the U.S. Department of Agriculture (USDA), Department of Energy (DoE), and the Centers for Disease Prevention and Control (CDC) to provide the public with an adequate understanding of sustainable technologies and their associated public health implications.

4.3. PROPOSED POLICY

Three policy alternatives have been developed for consideration; these alternatives will later be assessed against a "Do Nothing" scenario to determine the benefits and risks of these policy options. A short summary on the execution and goals of each policy alternative is provided below.

4.3.1. Alternative 1: Amend RCRA

The first alternative proposed is to "Amend the Resource Conservation and Recovery Act (RCRA) to mandate waste stream pre-treatment prior to disposal." This alternative is a "Do or Die" approach in which non-compliant solid waste facilities will be fined annually until a permitted pre-treatment system is operational and active. Some proposed pretreatment options include large-scale composting, complete incineration, and energy recovery incineration. Currently, the U.S. EPA outlines three (3) acceptable forms of large-scale composting - Windrow, Aerated Static Pile, and In-Vessel Composting (U.S. EPA, 1995; Tchobanoglous et al., 2003). Composting provides several key benefits over landfilling; these benefits include reduced leachate production and the creation of a viable resource – compost (Robinson and Fu, 2011; Partanen et al., 2011). The second method – incineration – has been effectively used to treat and dispose of medical wastes and certain hazardous waste (U.S. EPA, 2011a). This method drastically reduces the waste volume, with all volatiles being vaporized during the incineration process and requires a relatively small land footprint (U.S. EPA, 2002; U.S. EPA, 1993). It is anticipated that this method will be preferred in high population density areas. Energy recovery incineration utilizes the combustion of municipal and commercial solid waste material to produce an essentially renewable energy stream. Other pre-treatment technologies may be accepted if proper documentation is provided to indicate that a waste volume reduction is achieved while still meeting acceptable environmental water, air, and soil quality standards.

To ensure that pre-treatment efforts are sufficient, a permitting process similar to the National Pollutant Discharge Elimination System (NPDES) program established with the Clean Water Act will be employed. These Pre-Treatment of Solid Waste (PTSW) permits will be managed and enforced by the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response (OSWER). Permits will establish a pre-treatment facilities maximum capacity, and will require monitoring of influent and effluent volumes and toxic contaminant concentrations. Additional manpower will be necessary for the execution of this amendment; therefore, a new division will be created to handle all permitting applications and related affairs within OSWER (U.S. EPA, 2012e).

4.3.2. Alternative 2: Elective Federal Program

The second proposed alternative, "Develop a community centric federal program encouraging and rewarding municipal solid waste reduction activities," is essentially an elective federal program. This act centers on effective and sustainable waste management in local communities nationwide. There are two primary aspects to this act; the first being a funding program for sustainable waste technology and the second being a monetary incentive for communities that meet a minimum waste reduction of 25%. The funding program will fund scientific research in the waste management field, repairs to existing solid waste treatment facilities, expansion programs for existing solid waste facilities, and start-up funds for new sustainable pre-treatment facilities like those mentioned for the previous alternative. To determine whether an effective reduction in overall waste volume has been attained, annual waste volumes will be compared to historical baseline waste volumes for each community (population increases will be accounted for accordingly). The monetary incentive allots a set amount per capita to be used by the local government. To maintain transparency, communities receiving the incentive funds will be required to report quarterly on the use of these funds. Acceptable allocations of these resources include aid for local school districts and local infrastructure repair projects falling within the guidelines set by the American Recovery and Reinvestment Act of 2009 (Office of Management and Budget, 2012). The goal of this alternative is to provide incentives for advancement in solid waste treatment practices focusing on local community contributions.

4.3.3. Alternative 3: Solid Waste "Carbon Credit" Marketplace

The third proposal is to develop a "carbon credit" marketplace for non-hazardous waste. With many industries pursuing zero waste technologies this allows companies to create offsets from the baseline for trading with companies that are producing excess waste. This alternative is designed to promote a public-private partnership allowing companies to reduce their wastes at an optimal cost. The goal of this policy alternative is a 25% waste reduction nationwide, and the privatization of pre-treatment practices will be encouraged to offset economic costs for widespread modifications to existing solid waste infrastructure.

Achieving a true "zero waste" society is not feasible with the current technology strategies being implemented in industrial practices; however, by allowing pre-treatment businesses to offset these waste volumes a viable reduction can be achieved. In order to achieve an effective "carbon credit" system in solid waste, the program will be developed and managed through the existing Environmental Credit Corporation which currently handles eligibility assessment, registration, reporting, monitoring, and verification activities for the greenhouse gas carbon credit system (Environmental Credit Corporation, 1999).

4.3.4. Do Nothing

The "Do Nothing" option merely addresses the risks and benefits of the existing policy with no proposed alterations being made. The existing policy for solid waste management is largely found in the Resource Conservation and Recovery Act (RCRA) legislation (40 *CFR* 239-258, 1996a). With this option 0% waste volume reduction is expected, furthermore, an increase in total waste volume will exist as the nation's population increases.

4.4. EVALUATION OF POLICY ALTERNATIVES

Several factors related to acceptance of policy change exist in the United States. At present concerns with the federal, state, and local budgets have limited the amount of money being funneled into progressive changes in policy as existing programs have priority on these funds. An exception to this rule exists if the policy change in question is being bolstered by public outcry – especially if the outcry concerns public health and welfare. The proposed solid waste alternatives have been evaluated based on political acceptance in the current clime; however, perceptions have also been provided for a political development requiring immediate response. The political evaluation is qualitative in nature and is merely a projected outcome, rather than the quantitative economic analysis outlined below. To improve the significance of the political analysis, it is proposed that a series of public surveys be issued to provide a more accurate evaluation of public perceptions related to the issue of municipal solid waste.

4.5. ANALYSIS OF ALTERNATIVES

4.5.1. Alternative 1: Amend RCRA

Of the potential alternatives, this mandated change to RCRA is the most politically abrasive in that it offers no leeway to its implementation and the associated costs will affect the public, private, and government sectors. The proposed pre-treatment mandate is the most effective approach to reducing the waste volume; nevertheless, it will also be the most negatively received. With the bulk of implementation costs typically coming from local governments and the public sector there will be difficulty in getting this legislature to pass in the current economic and political climate. This form of political alternative is most effective when a need for policy change stems from a disaster or from a documented risk to public health and welfare. These reactionary changes can be all-encompassing and straightforward to achieve their goal due to the need to quell the public outcry.

The primary assumption being made for Alternative 1's implementation plan is that these pre-treatment facilities are operating in conjunction with an active landfill, reducing the total number of landfills failing to meet the pre-treatment amendment to 1780. It will also be assumed that only half of the landfills projected will be constructed due to the reduction in waste being landfilled due to the increase of wastes to incineration and composting.

There are two basic categories for composting: yard trimmings (YT) and municipal solid waste (MSW). The type of facility greatly affects the associated costs. Yard trimming facilities are generally less complex and have low overhead. Complicated, and costly, MSW composting facilities utilize in-vessel digesters and windrows to treat the organic fraction of waste. These costs come with a benefit, with reductions of 50% total waste volume being feasible during municipal waste composting (Spencer et al., 2007; Spencer, 2010). Table 22 highlights the average amounts of waste being treated via landfilling, recycling, composting, and incineration in 2010 and estimates for 2025. Average facility capacities were used to determine the expected number of facilities required to implement the policy change and manage the increased waste stream for 2025 projected waste generation.

Table 22. The number of facilities, and average facility capacity, required to meet 2025 demands assuming the implementation of Alternative 1.

Technology	2010	2025	Change in Generation	Avg Annual Facility Capacity (tons)	# of New Facilities
Landfilling	269,780,521	213,564,720	-56,215,801	140000	-402[1]
Recycling	70,816,968	85,425,888	14,608,920	7500	1948
Composting (YT)	24,497,252	64,069,416	39,572,164	4000[2]	2473
Composting (MSW)				100000[2]	297
WTE	25,926,285	64,069,416	38,143,131	350000	109

[1] It is likely that no new facilities will need to be constructed during the 20 year period.
[2] 25% of new Composting facilities will by YT and 75% MSW, due to the low current number of MSW facilities.

4.5.2. Alternative 2: Elective Federal Program

Legislature programs that bolster community efforts and involvement are typically looked favorably upon by the public and lawmakers. These incentive programs that reward "good behavior" and provide the means for advancement of a technology allow the public to participate and feel a closer connection and involvement with governmental decisions. The incentives outlined in this policy alternative go directly to the community and largely benefit the local governments and the public. This approach is also less abrasive than that expressed in Alternative 1, allowing communities to choose whether or not they wish to participate rather than forcing them to fund costly advancements to their solid waste infrastructure. Furthermore, Alternative 2 does not require public outcry to get the ball rolling, and can be introduced under most political and economic climes.

Publications by the U.S. EPA indicate that greater than 20% of the MSW stream can be recycled (U.S. EPA, 2012f; U.S. EPA, 1999). Certain states are already achieving the 20% reduction in waste via recycling, and include California, Iowa, Kansas, Maine, Maryland, Massachusetts, Oklahoma, Oregon, Pennsylvania, South Carolina, and Vermont (van Harren et al., 2010). Similarly, waste reductions of 50% are feasibly during municipal solid waste composting; therefore incentives will be provided for communities who meet these reduction percentages.

Table 23 contains the anticipated

Table 23. The number of facilities, and the average facility capacity, required to meet 2025 demands assuming the implementation of Alternative 2.

Technology	2010	2025	2025 With Incentives	Avg Annual Facility Capacity (tons)	Total # of New Facilities	# of Incentive Facilities
Landfilling	269,780,521	294,719,313	24,938,792	140000	178	0
Recycling	70,816,968	76,883,299	78,233,299	7500	1740	900
Composting (YT)	24,497,252	25,627,766	28,123,766	4000[1]	280	48

Composting (MSW)				100000[1]	49	48
WTE	25,926,285	29,899,061	36,619,061	350000	107	96

[1] 25% of new Composting facilities will by YT and 75% MSW, due to the low current number of MSW facilities.

waste treatment by technology for Alternative 2, and projected values are provided assuming 10 percent of communities opt into the incentive plan.

4.5.3. Alternative 3: Solid Waste "Carbon Credit" Marketplace

This method is largely controlled by the companies and individuals involved in the solid waste industry and the federal government. This is both a good and bad thing in terms of public perception. It's considered favorable in that the "responsible" parties are in charge of cleaning up their act; yet, if the public feels like these parties are shirking their duties, then it can be considered a negative policy alternative. The proposed carbon credit policy does not address community input and public inclusion making it limited in its effectiveness in waste reduction which may also limit its attractiveness as a policy alternative.

In order to implement a "carbon credit" marketplace, a significant amount of start-up is required initially by the federal government to develop baseline waste reduction values for varying industries. The credit system will be centered on the concept that for every ton of waste reduced (either at the source or via composting and incineration technologies) a monetary credit will be created. This credit value should be higher than average waste tipping fees to provide incentive of program participation. Documentation will need to be collected and a system of company registry will be used to document waste trends for these businesses. The determination of the value of an individual waste "credit" was considered outside of the scope of this research.

4.5.4. Alternative 4: Do Nothing

A common adage is "if it's not broke, don't fix it" and that provides a strong backing for the "Do Nothing" alternative. If both the public and the related industry feel this way, then this may be the best option. However, in situations where the affected industry believes the policy needs to be changed to provide more guidance or structure this can be a poor choice. Typically, if the related industry thinks that there is a problem, it will only be a matter of time before you have a situation that can evolve into a major source of negative publicity. Furthermore, the "Do Nothing" is a poor alternative selection in the event of a public outcry. The public wants to see their government taking the necessary steps towards fixing the problem, and no amount of hand-waving will achieve this goal.

To meet the waste disposal demand for the 2025 projected population, new landfilling facilities will have to be designed and constructed throughout the country. No change in the percentage going to landfilling, recycling, composting, or WTE were made. The estimated change in waste technology distributions are presented in Table 24.

4.5.5. Summary of Evaluation

Overall, the political acceptance of a policy depends largely on the public perception of the issue. In the current political atmosphere, fewer regulations are considered more favorable especially if they have a large economic impact. However, if the policy is designed to make the public feel like they have control, then it may be more favorably regarded. As mentioned previously, strict mandates in policy are typically not well received unless there is a public outcry for immediate change. An outcry for the protection of public health and welfare in the 1970s is what led to the formation of the U.S. EPA and the bulk of the environmental policy currently enacted today.

Table 24. The number of facilities, and their average annual capacities, required to meet 2025 demands assuming that no change in policy is made, and a similar ratio between technologies exists.

Technology	2010	2025	Change in Generation	Avg Annual Facility Capacity (tons)	# of New Facilities
Landfilling	269,780,521	294,719,313	24,938,792	140000	178
Recycling	70,816,968	76,883,299	6,066,331	7220	840
Composting	24,497,252	25,627,766	1,130,514	4030	281[1]

WTE	25,926,285	29,899,061	3,972,776	368000	11

[1] One MSW composting facility has been included in this number based on existing ratios.

4.6. DECISION – MAKING PROCESS

4.6.1. Stakeholder Involvement

In the United States, public awareness of an environmental issue is often the driving force behind policy reform. Often, research findings alone are not enough to induce change unless they have been brought to light to the general public by environmental lobbyists or media outlets. In the event that public outcry occurs over municipal solid waste (MSW) practices, then the decision-making mode will automatically defer to the Emergency Action plan. This type of event occurred in the Naples Waste Management Crisis that reached the global media markets in 2008 (Vinci, 2008).

Due to the existing political atmosphere surrounding solid waste management policy and technology, the need to incorporate the public in the decision-making process is relevant. For a change in solid waste policy, a decision-making process consisting of Analysis Centered (AC) and Collaborative Learning (CL) aspects was selected. The resulting process is explained below.

Prior to involving the public, a knowledge base must be established concerning the issue at the local, state, and federal levels. Initial efforts towards the compiling of nationwide solid waste data have been successful; however, data at the state government level is not sufficient at this time and further collection of data from local governments is required. Using the methods outlined in the AC method an analyst committee will be formed to collect operations information and waste characterization data from the 1908 landfills, 115 MSW incineration plants, the 3000 voluntary composting facilities, 9000 curbside recycling programs, and 13 MSW composting facilities. This data, in addition to being utilized as a verified data resource for municipal waste management, will be used to select communities for public surveys.

Once the initial database has been developed, public surveys concerning awareness of costs, health and safety issues, risks, environmental impacts, and general MSW infrastructure will be developed. Prior to survey implementation, communities will be grouped into categories based on whether their community's MSW is pre-treated or is sent straight to landfill. Of these categories random communities will be selected and polled to determine whether there are differences in public awareness for communities with pre-treatment facilities versus communities that use traditional landfilling technology. This information will help develop risk management plans and community outreach methods necessary to have a successful collaborative learning decision-making structure.

Using statistical analysis methods, the results of the proposed public surveys will be compiled and analyzed to determine the current state of public perception regarding solid waste management and infrastructure. To communities exhibiting very little awareness or knowledge about their waste management, a series of public forums will be scheduled promoting community involvement in solid waste management practices. These public forums will largely consist of an explanation of what happens to their waste (and any pertinent treatment strategies it undergoes) and an introduction to problems with increased waste demand on landfill sites. Public forums, or informational sessions, will involve local governments and the general public, and the primary focus of these forums is to increase public awareness of solid waste issues and their potential impacts on public health, welfare, and the environment. These forums can also be used to determine the important criteria needed to guide future policy changes.

The results of the initial public surveys and forums will be used to construct policy options, and specifics on political and economic impacts will be determined. A second series of public surveys will be developed and issued via phone and random digit dialing to the nationwide population at random to determine public opinions on the proposed policy options. Based on these results the favored option(s) will be presented to the EPA. At this point further policy decisions will be made by pertinent administrators and the federal government.

4.6.2. Policy Criteria

Prior to evaluating policy alternatives with a decision matrix, a set of policy objectives must be developed with all affected parties represented if possible. For this proposal the objectives favoring the aims of the U.S. Environmental Protection Agency, federal policy-makers, local governments, and the public will be addressed. Additionally, the policy criteria selected for use in the decision matrix have been assigned weights. The process of weight selection required several iterations to create an optimal matrix. There are eight criteria in the final decision matrix, and the weights range between 5% and 20%, totaling 100%.

Maximize landfill lifetimes – By reducing the number of active landfills the potential environmental impact of solid waste disposal onto the surrounding soil and water systems can be diminished. This follows the principle of quality rather than quantity. This criterion is the focus of the proposed environmental policy, and therefore was weighted the highest at .20, or 20%. Regardless of how well a policy performs in the other categories, the overall volume of waste being landfilled must be minimized to prevent negative impacts to public health and to promote a more sustainable society.

Minimize air pollution impacts from solid waste treatment – Harmful greenhouse gas and heavy metal particulates must be reduced to protect the environment and public health. Air pollution poses a measureable risk to the environment and public health, a policy solution that minimizes these risks would be favorable. Due to concerns of negative impacts from air contaminant exposure, this criterion was granted a weight of 0.15, or 15%.

Minimize water pollution impacts from solid waste treatment – Leachate treatment from landfills can be quite costly, especially if it meets a hazardous waste criterion. The proposed policy alternative should lessen the leachate and breakthrough groundwater contamination risks. This criterion is similar to the previous one involving air pollution. Water pollution can greatly impact human welfare and the environment, and landfills produce harmful leachate that may breakthrough protective barriers and enter the aquifers. The proposed policy alternative should lessen the probability of widespread water contamination, and thus this criterion was granted a weight of 0.15, or 15%.

Maximize the acceptability of waste treatment as an area in the policy needing reform –Does the alternative appeal to the public, or would it be considered controversial? This criterion was designed to help involve the public, and as highlighted in the explanation of the proposed stakeholder involvement, the public will be involved as the solid waste policy progresses through the decision-making method. While public acceptance is important, it was determined that its impact on the selected policy is less than that of the three previous criteria. Policy promoting public health, welfare, and environmental quality must be kept central; however, picking a policy option that outright defies the public's wishes has negative effects resulting in this criterion being weighted 0.10, or 10%.

Minimize policy implementation costs – The more costly a technology is to implement, the more difficult it will be for it to be accepted by policy-makers and stakeholders. Important considerations include whether land purchases will be required to implement the new policy, and in the event that the new technology controversial, will it require a risk management program? With budget issues being present at every level of government, initial implementation costs must be kept to a minimum. The current economy cannot support high initial costs projects and policy changes at this time; therefore, this criterion was weighted at 0.15, or 15%.

Minimize facility operation and maintenance costs – implementing new technologies can result in costly personnel training and increased equipment maintenance fees. These costs would directly affect the local governments or stakeholders maintaining the solid waste facility. The costs incurred in facility operations are often forgotten when promoting policy. These costs, while not as large as initial implementation costs, can cause an accepted policy to fail several years down the road as federal funding ceases and local funding takes over. This criterion was assigned a weight of 0.10, or 10%, as the present needs and demands overshadow those of the future.

Increase job creation in the solid waste management sector – The development of local jobs can play a key role in gaining public acceptance, especially if both technical and non-technical jobs are created. Nevertheless, this is more of an added perk and not considered a "making it or breaking it" criterion. This criterion was weighted at 0.05, or 5%.

Minimize overall costs of waste disposal to public sector – Sometimes benefitting the environment is not enough if the cost to the public in terms of increased taxes and handling fees for waste disposal exist. Public dumping may ensue if the cost increase is past being acceptable economically. It is important that the citizens do not shoulder the bulk of the financial burden through increased disposal costs and local fees. If waste disposal costs exceed an "acceptable" amount then individuals will turn to illegal dumping practices causing further damage to the environment and increasing the risk to public health. It should be kept in mind that many communities provide waste collection which helps curb illegal dumping practices. This criterion was assigned a weight of 0.10, or 10%.

These eight criteria address environmental, political, and economic issues related to solid waste treatment. In conclusion, the policy alternative that best meets these objectives will be selected for recommendation. It was determined that the criterion “Maximize Landfill Lifetimes” should be the most heavily weighted, and that the criterion identifying an “Increase in Job Creation in Solid Waste Sector” as the least heavily weighted criterion.

4.7. DECISION MATRIX

Using the decision weights outlined in Section 5.2, each alternative was evaluated using a decision-making matrix. For reference, the eight evaluation criteria – and their corresponding weights in the matrix – are as follows: Maximize Landfill Lifetimes (20%), Minimize Air Pollution Impacts (15%), Minimize Water Pollution Impacts (15%), Maximize Public Acceptance (10%), Minimize Implementation Costs (15%), Minimize Operations and Maintenance Costs (10%), Increase Jobs (5%), Minimize Cost to Public (10%). Two of the evaluated alternatives tied for the highest score, 6.40; the results of the matrix evaluation are provided in Table 16 and the scores for each alternative are summarized below.

4.7.1. Alternative 1: Amend RCRA

The strictest policy alternative received an overall score of 5.75 in the decision matrix. It scored well in “Maximize Landfill Lifetimes”, “Minimize Air Pollution Impacts,” “Minimize Water Pollution Impacts,” and “Increase Jobs”; however, it is the most costly alternative proposed and also has an anticipated low public acceptance rate. This policy was deemed the most be uncompromising politically, and would likely not be well-received except as a response to an emergency action situation involving a critical threat to public health or the environment.

4.7.2. Alternative 2: Elective Federal Program

The elective federal program alternative received an overall score of 6.40 in the decision matrix, making it one of two favored policy options. This alternative scored moderately well in all of the criteria evaluated, having a particularly favorable public acceptance score. This is due to this alternative’s focus on community involvement.

The elective nature of this policy will both provide issue awareness to the public whilst allowing varying degrees of response. The research grant portion of this policy will also promote technological advances in solid waste technology.

4.7.3. Alternative 3: Solid Waste "Carbon Credit" Marketplace

The "carbon credit" marketplace alternative received an overall score of 6.40 in the decision matrix, making it the second favored policy option. This policy had a wider range of scores than Alternative 2, and scored particularly well in the categories concerning cost minimization. A lower public acceptance score was assigned to this alternative due to the policy's focus on industry rather than community. This policy will be successful at reducing waste volumes from the commercial and industrial sector; however, little focus is placed on community, or public, involvement.

4.7.4. Alternative 4: Do Nothing

The "Do Nothing" policy alternative received an overall score of 3.75 in the decision matrix. Its low score is primarily due to the low score for "Maximize Landfill Lifetimes," "Minimize Air Pollution Impacts," and "Minimize Water Pollution Impacts." While these scores have significantly lowered the overall evaluation of this alternative, it does present a higher public acceptance rate and lower cost to the public than several of the other alternatives.

Table 25. Decision-matrix evaluation for the proposed solid waste policy alternatives.

Alternative	Max. Landfill Lifetimes	Min. Air Pollution Impacts	Min. Water Pollution Impacts	Max. Public Acceptance	Min. Implemen t. Costs	Min. O&M Costs	Increase Jobs	Min. Cost to Public	FINAL SCORE
Amend RCRA	10	8	8	1	1	2	10	4	5.750
"ARRA" SW Policy	**7**	**6**	**6**	**8**	**6**	**6**	**6**	**6**	**6.400**

SW Carbon Credit	**4**	**6**	**6**	**4**	**10**	**8**	**2**	**10**	**6.400**
Do Nothing	1	2	2	8	6	4	1	8	3.750

4.8. POLICY RECOMMENDATIONS

Overall, the recommendation is that both Alternatives 2 and 3 are proposed in the hopes of aligning both industry and community stakeholders in the development of sustainable waste reduction programs. While Alternative 2 is more costly, it is likely to be the most effective; whereas, Alternative 3 may be easier to implement with the advent of the global carbon marketplaces affecting many industrial sectors. Based on the funds available for this policy reform, these two alternatives may be implemented concurrently or in stages to achieve the most economical outcome. The marriage of these two policy alternatives will promote an all-encompassing, yet wholly elective sustainable solid waste infrastructure benefitting a variety of stakeholders. It is recognized that there may be some difficulties in garnering political acceptance for these alternatives in the current political and economic climate; however, the implementation of the "Stakeholder Involvement" strategy outlined in this report can improve public awareness and interest in municipal solid waste disposal practices and the related legislation.

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CHAPTER V: CONCLUSION

5.1. *Final Statements*

At present, solid waste management practices are not sustainable and will be further strained with the projected population of the United States reaching 350 million by 2025 (U.S. Census Bureau, 2005). With limited landfill capacities, many local and state governments are pursuing waste diversion tactics, such as biosolids land application and municipal waste composting, to alleviate the pressure. The two environmental risk perception surveys presented in this study are critical to improving public awareness, involvement, and acceptance of these waste diversion alternatives.

The findings discussed in Chapter 2, highlight that the majority of the residents in the two south-eastern United States communities do not currently have a favorable view of biosolids. Many of these findings stem from the public's dissatisfaction with the level of stakeholder involvement in research and decision-making processes. The following are significant perceptions of risks associated with biosolids treatment, regulation, and land application:

- Benefits from biosolids recycling do not offset the perceived health and safety risks, given current perceptions and knowledge base.
- Females and Amelia County residents perceived that biosolids were inadequately treated for land application.
- Female respondents perceived significantly greater health and safety risks from biosolids applications than males.
- The "outraged" Amelia County residents responded with stronger attitudes against biosolids reuse than the Knox Metro residents.

Community-specific outreach programs will need to be developed to address differences in perception between rural and urban populations as well as between genders to reduce the negative connotation associated with biosolids in the south-eastern United States. A notable finding of the biosolids survey was that a greater health risk was associated with exposure to biosolids than animal manure by all respondents. This led to the development and execution of an animal manure risk perception survey, discussed in Chapter 3, to the populations previously polled for the biosolids survey.

The animal manure survey responses indicate that the public is more accepting of the risks posed by animal manure land application methods. In order, to find common ground between biosolids and animal manure risk perceptions, the following differences must be addressed:

- Both communities indicated that they were more adequately informed about the risks associated with animal manure than those associated with biosolids.
- Greater health risks were associated with exposure to biosolids than animal manure by all respondents.
- Gender and location, rather than level of education, contribute significantly to risk perceptions related to biosolids and animal manure land applications.

As mentioned previously, these differences amongst the general population must be addressed in order to enact a successful amendment to existing policy. However, with the promising advances made in risk management for nuclear activities in the United States, the author is confident that similar accomplishments can be made in risk management for biosolids land application and other non-traditional waste diversion techniques.

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APPENDICES

APPENDIX I: SURVEY QUESTIONNAIRES

Biosolids Survey

PUBLIC PERCEPTION OF EXPOSURE AND RISK CONCERNING REUSE OF BIOSOLIDS

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TELEPHONE SURVEY

Hello, my name is _________ and I am calling from the Social Science Research Institute at the University of Tennessee. I am conducting a survey to find out what people think about an environmental issue. The survey will last less than ten minutes. May I speak to the person over 18 with the most recent birthday?

The following statements concern the reuse of **biosolids**. As you may know, biosolids are the solid materials separated from municipal sewage and further treated using advanced sanitation methods. In many areas of the United States, biosolids are spread onto the land after treatment. Please indicate your level of agreement for the following statements using a 1 to 5 scale.

1. Current state and federal laws are sufficient to protect public health when biosolids are applied to land.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

2. Biosolids receive adequate treatment at the wastewater treatment plant to protect public health.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

3. The presence of disease-causing microorganisms in biosolids, such as bacteria and viruses, are a significant risk to human health.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

4. Applying biosolids to land contaminates water in nearby streams and rivers.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

5. We risk contamination of the groundwater when biosolids are applied to land.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

6. My family would be at a higher health risk if my neighbors applied **biosolids** to their land.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

7. My family would be at a higher health risk if my neighbors applied **animal manure** to their land.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

8. I am willing to tolerate the odor emitted during and after land application of biosolids.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

9. The odor emitted by biosolids presents a risk to my health when breathed.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

10. Reuse of biosolids in my community will lower property values.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

11. To provide the highest level of safety for biosolids, I am willing to double my current sewage bill.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

12. I am willing to accept a higher health risk if it results in a cheaper cost to me.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

Please select one of the three possible responses "True, False, or Don't Know" for each of the following questions.

13. According to the Environmental Protection Agency, health risks associated with the use of biosolids are greater than the health risks associated with the use of animal anure.
    1) True 2) False 3) Don't know

14. Exposure to biosolids presents an equal health and safety risk to both children and adults.
    1) True 2) False 3) Don't know

15. The Environmental Protection Agency currently regulates the levels of disease-causing bacteria in biosolids.
    1) True 2) False 3) Don't know

16. Biosolids contribute nutrients, such as nitrogen and phosphorous, to the soil.
    1) True 2) False 3) Don't know

17. Land application is currently the cheapest method of biosolids disposal.
    1) True 2) False 3) Don't know

18. According to the Environmental Protection Agency, public health and safety risks from biosolids exposure are low.
    1) True 2) False 3) Don't know

The following are possible options for the use of biosolids. Please indicate your level of agreement for the following options using the 1 to 5 scale.

Biosolids can be safely ……..

19. Applied to pastures where the hay is used to feed animals grown for human consumption.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

20. Applied on food crops.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

21. Applied to highway medians.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

22. Applied to home vegetable gardens.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

23. Applied to your yard and to flower beds around your home.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

24. Applied to public areas such as parks, playgrounds, and athletic fields.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

Please indicate your level of agreement for the following statements using the 1 to 5 scale.

25. I am satisfied with the procedures used to involve citizens in biosolids decision-making.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

26. Decisions about biosolids management in my community have been made in an open way.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

27. I feel that I am adequately informed about the potential risks of reusing biosolids.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

28. Biosolids are a valuable resource that should be reused.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

29. The risks to public health outweigh the benefits derived from the reuse of biosolids.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

30. Based on my perception of risks and benefits, I would be in favor of land application of biosolids.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

How trustworthy do you think the following groups are in providing health and safety information about biosolids?

31. Local government
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

32. Local utility company
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

33. Private company involved in land application
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

34. Consulting engineers
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

35. University scientists
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

36. Community health nurses
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

37. Medical doctors
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

To finish this survey, I would like to get some information about you for classification purposes. This information will be kept confidential.

38. In which of the following settings do you live?
    1) Rural 2) Suburban 3) City

39. How close do you live to a biosolids land application site?
    1) Within my neighborhood 2) Within my community
    3) Not applied in my region 4) Don't know

40. Is your house currently hooked to a septic system or the local sewer system?
1) Septic 2) Sewer 3) Other

41. Are you male or female? 1) Male 2) Female

42. What is your age?

43. What level of education have you received?
1) Did not complete high school 2) Graduated from high school
3) Some college or university 4) Graduated from college or university
5) Completed masters degree or higher

44. To which ethnic group do you belong?
1) Caucasian (white) 2) Black 3) Hispanic 4) Asian 5) Native American
6) Other

45. And lastly, for statistical purposes only, which category best describes your total household income before taxes in 2002.
1) Under $25,000 2) 25,000-50,000 3) 51,000-100,000
4) more than 100,000

Thank you for participating in this survey

COMPARATIVE ASSESSMENT OF PERCEIVED EXPOSURE AND HEALTH RISKS PERTAINING TO LAND APPLICATION OF ANIMAL MANURE AND HUMAN BIOSOLIDS

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TELEPHONE SURVEY

Hello, my name is _________ and I am calling from the Social Science Research Institute at the University of Tennessee. I am conducting a survey to find out what people think about an environmental issue. The survey will last less than ten minutes. May I speak to the person over 18 with the most recent birthday?

The following statements concern the reuse of animal manure. For this study, animal manure is defined as the solid waste material generated from farm animals. On many farms in the United States, animal manure is spread onto the land after treatment. Please indicate your level of agreement for the following statements using a 1 to 5 scale.

1. Current state and federal laws are sufficient to protect public health when animal manure is applied to land.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

2. Animal manure receives adequate treatment to protect public health at the farm site where it is generated.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

3. Applying animal manure to land contaminates water in nearby streams and rivers.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

4. We risk contamination of the groundwater when animal manure is applied to land.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

5. My family would be at a higher health risk if my neighbors applied animal manure to their land.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

6. My family would be at a higher health risk if my neighbors applied **treated human waste** to their land.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

7. I am willing to tolerate the odor emitted during and after land application of animal manure.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

8. The odor emitted by animal manure presents a risk to my health when breathed.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

9. Recycling of animal manure in my community will lower property values.
   1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

10. To provide the highest level of safety for animal manure recycling, I am willing to pay up to 10 percent more for agricultural products at the grocery store.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

11. I am willing to accept a higher health risk if it results in a cheaper cost to me for agricultural products.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

Please select one of the three possible responses "True, False, or Don't Know" for each of the following questions.

12. More **human** manure is produced than animal manure in a year.
    1) True 2) False 3) Don't know

13. Animal manure receives more treatment than human manure before recycling onto land.
    1) True 2) False 3) Don't know

14. According to the Environmental Protection Agency, health risks associated with the use of animal manure are greater than the health risks associated with the use of treated human waste.
    1) True 2) False 3) Don't know

15. Microorganisms that can cause human diseases are present in animal manure?
    1) True 2) False 3) Don't know

16. The levels of disease-causing bacteria in animal manure are strictly regulated by federal agencies such as the United States Department of Agriculture and the Environmental Protection Agency.
    1) True 2) False 3) Don't know

17. Exposure to animal manure presents an equal health and safety risk to both children and adults.
    1) True 2) False 3) Don't know

18. Animal manure contributes nutrients, such as nitrogen and phosphorous, to the soil.
    1) True 2) False 3) Don't know

The following are possible options for the use of treated animal manure. Please indicate your level of agreement for the following options using the 1 to 5 scale.

Animal manure can be safely ……..

19. Applied to pastures where the hay is used to feed animals grown for human consumption.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

20. Applied on food crops.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

21. Applied to highway medians.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

22. Applied to home vegetable gardens.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

23. Applied to your yard and to flower beds around your home.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

24. Applied to public areas such as parks, playgrounds, and athletic fields.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

Please indicate your level of agreement for the following statements using the 1 to 5 scale.

25. I am satisfied with the procedures used to involve citizens in animal manure decision-making.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

26. Decisions about animal manure management in my community have been made in an open way.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

27. I feel that I am adequately informed about the potential risks of reusing animal manure.
    1) Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

28. Animal manure is a valuable resource that should be reused.
    1)Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

29. The risks to public health outweigh the benefits derived from the reuse of animal manure.
    1)Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

30. Based on my perception of risks and benefits, I would be in favor of land application of animal manure.
    1)Strongly disagree 2) Disagree 3) Don't know 4) Agree 5) Strongly agree

How trustworthy do you think the following groups are in providing health and safety information about animal manure?

31. Local government
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

32. Federal government
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

33. Large corporate farms
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

34. Consulting engineers
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

35. University scientists
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

36. Community health nurses
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

37. Medical doctors
    1) Not trustworthy at all 2) Somewhat trustworthy 3) Highly trustworthy

To finish this survey, I would like to get some information about you for classification purposes. This information will be kept confidential.

38. In which of the following settings do you live?
    1) Rural 2) Suburban 3) City

39. How close do you live to an animal manure land application site?
    1) Within my neighborhood 2) Within my community
    3) Not applied in my region 4) Don't know

40. In the last 12 months, have you used animal manure on your garden or around your home?
    1) Yes 2) No 3) Not sure

41. Are you male or female? 1) Male 2) Female

42. What is your age?

43. What level of education have you received?
    1) Did not complete high school 2) Graduated from high school
    3) Some college or university 4) Graduated from college or university
    5) Completed masters degree or higher

44. To which ethnic group do you belong?
    1) Caucasian (white) 2) Black 3) Hispanic 4) Asian 5) Native American
    6) Other

45. And lastly, for statistical purposes only, which category best describes your total household income before taxes in 2003.
    1) Under $25,000 2) 25,000-50,000 3) 51,000-100,000
    4) More than 100,000

Thank you for participating in this survey

APPENDIX II: RESCALED DATA

Biosolids Survey Responses – Rescaled

See File 1: Biosolids Rescale Insert.docx

Animal Manure Survey Responses - Rescaled

See File 2: Animal Manure Rescale Insert.docx

APPENDIX III: BINARY DATA

Biosolids Survey Responses - Binary

See File 3: Biosolids Binary Insert.docx

Animal Manure Survey Responses - Binary

See File 4: Animal Manure Binary Insert.docx

VITA

Lauren Raup-Plummer was born in Greenville, South Carolina in 1985. She graduated with a Bachelor of Science degree in Civil Engineering with a focus in Environmental and Water Resources and a minor in Geosciences from Virginia Polytechnic Institute and State University in May 2007. Lauren pursued a career as a geotechnical engineering staff professional for a year and a half at S&ME, Inc. in Raleigh, North Carolina prior to commencing her graduate education. In January 2009, Lauren entered the University of Tennessee, Knoxville for her Master of Science in Environmental Engineering and has researched a diverse set of topics involving waste materials and instructed the undergraduate environmental engineering laboratory course (CE 482).