Households� Preferences for Plumbing Materials

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1. Introduction

Consumers' decisions on plumbing material selection are dictated by various factors, including state and federal regulations, service providers, and individual household preferences. The regulations and standards of the federal, state, and local governments have major impacts on the plumbing material chosen for installation in a private house. For example, the use of plastic plumbing material, such as PEX, has been approved in all U.S. states except for California and Massachusetts, where the material installation requires local jurisdiction acceptance. Similarly, in some parts of Florida, PEX is preferred due to the seriousness of pinhole leak[1] problems (NSF, 2008). These regulations influence services provided by plumbers, material producers (e.g. pipe manufacturers, interior coating providers), and water utility companies. For example, general contractors are the primary decision-makers of plumbing material installation in new houses, while utility companies respond to corrosion threats by adding corrosion inhibitors to drinking water treatment. Consequently, all service providers influence consumer decisions, regarding the best plumbing material for private properties.

Homeowners have an important stake in finding plumbing system appropriate for their households, and they should rely not only on expert advice, but also acquire information on plumbing material attributes such as price, health impact, longevity, and corrosion resistance, in order to make informed investment decisions about plumbing systems for their homes. For example, health effects, water taste and odor have been found to be the most important factors in consumers' evaluations of plumbing material for home use (Lee et al., 2009). Additionally, households are willing to pay up to $4,000 when guaranteed a leak-free plumbing system for 50 years (Kleczyk et al., 2006). Information on consumer preferences for drinking water plumbing attributes can be useful not only to individual households, but also to policymakers, program managers, water utilities, and firms with interests in drinking water infrastructure.

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[1] Pinhole Leaks are a small holes that commonly are caused by pitting corrosion, a type of corrosion concentrated on a very small area of an inner pype. In most cases, pinhole leaks are hard to detect, if they are visible, they appear as green, wet area on pipe and porcelain fixtures (Kleczyk & Bosch, 2008).

The public perceptions of corrosion risk and cost of prevention play a fundamental role in consumers' drinking water decisions. Homeowners' perceptions of risk and cost of prevention may affect households' decisions on plumbing material repairs and replacement, as well as the type of material used. When informed about the attributes of each plumbing material alternative, consumers can decide on the most preferred plumbing system. The decision of choosing an appropriate plumbing material is based on various plumbing material attributes, such as cost (material cost plus labor and installation cost), health effects, corrosion susceptibility, strength, property real estate values, and behavior in the case of a fire (Champ et al., 2003).

As it is important to learn household perceptions and preferences for drinking water infrastructure, the chapter objective is to investigate homeowners' preferences for plumbing materials (i.e. copper, plastic, an epoxy coating), as well as preventive techniques against corrosion based on households' experiences with plumbing material failures. In 2007, a survey of a Southeastern Community in the United States was conducted in order to meet these goals, and obtain information on the prevalence of plumbing material failures, householders' experiences with plumbing material failures, the cost of repairs and property damages due to the material failures, and household preferences for plumbing systems.

The objective of the study is fulfilled by analyzing in-depth the information of the prevalence of home plumbing corrosion, preventive measures taken against corrosion, as well as the financial, health, and time costs associated with repairing faulty plumbing systems. In addition, analyses are performed to elicit household preferences for plumbing materials, and to identify the attributes important to choosing home plumbing systems. Summary statistics as well as regression methods, such the Ordered Logit model, are employed to support the study, and provide insight into the scale of corrosion in the community, the financial burden accrued from repairing the problem, and finally recommendation for the best plumbing materials for household use.

The knowledge gained from this chapter can be helpful in the design of public policy aimed at corrosion prevention. The research provides information to federal and state officials, plumbers, plumbing material manufacturers, and utility company managers on the financial burden individual households are willing to take on to avoid corrosion. In addition, the study should help in bridging the gap between the perceptions of the public and drinking water infrastructure experts, regarding the problem of pinhole leaks and other corrosion related issues.

2. Literature review

As mentioned above, the household decision-making process with regards to choosing a plumbing material for a private residency is complicated, and involves several factors, such as federal, state, and local standards and regulations, corrosion risk perceptions of drinking water as viewed by infrastructure service providers, insurance companies, households, as well as the financial impact of corrosion prevention. The regulations and standards of the federal, state, and local governments have major impacts on the plumbing material chosen for installation in a private house. These regulations influence the services provided by plumbers, home builders, material producers, and water utility companies (Lee et al., 2009).

To make an informed decision about the optimal plumbing material for their home, homeowners need information on the various risks involved in choosing plumbing systems. When informed about the plumbing material characteristics, the consumers are able to decide on an alternative most preferable to them based on the preference trade-offs among plumbing materials' attributes. Households make decisions on a plumbing alternative when either replacing an existing system or installing a plumbing system in a new house. Each alternative has advantages and disadvantages that impact health and the overall cost of installation and maintenance. The problem becomes more complex as consumers think in terms of cost (material plus labor charges), taste and odor of the water, corrosion problem, longevity of the pipe system, fire retardance, convenience of installation or replacement, plumbers' and general contractors' opinions or expertise, and proven record in the market. Householders weigh each of these attributes in order to choose the most preferred option for their houses (Lee et al., 2009).

For example, Lee et al. (2005), utilizing the AHP method, studied the preferences for plumbing materials of Virginia Tech potable water experts. Participants ranked the health effects, reliability, taste and odor, and longevity as the most important attributes when choosing a plumbing material. Property value and fire resistance were listed at the bottom of the ranking. These results showed that health, water taste and odor dominate preferences for plumbing materials. Lack of reliability resulting in the need to repair the damage associated with pipe corrosion relates to stress and a worry about future leaks (Lee et al., 2005).

There are several plumbing material types for a householder to choose from when deciding on a plumbing material to be installed in a house: copper, plastic (CPVC and PEX), and stainless steel. According to Marshutz' survey (2000), copper is used in nearly 90% of homes in the U.S. followed by PEX (cross linked polyethylene) with a 7% installation rate, and CPVC (chlorinated polyvinyl chloride) with a 2% installation rate. Telephone surveys of plumbers conducted in 2005 show an increased use of plastic pipes, due to easier handling in installation and lower material cost (Scardina et al., 2007).

Copper is the most widely used material in residential plumbing and has several advantages, including affordability, fire resistance, few health hazards, and durability. Woodson (1999) studied the performance of different plumbing material alternatives: copper, CPVC, and PEX. He found copper pipes generally perform well, except for cases involving major leak problems (Woodson, 1999). Due to increased pinhole leak incidents reported in hotspot areas of the U.S. (eg. Washington, D.C. suburbs and Sarasota, Florida), many consumers replaced copper with other options. Concerns with copper pipes include a metallic taste, especially with long stagnation periods and increased absorption of residual disinfectant by the pipe walls. High levels of copper can cause nausea, vomiting, and diarrhea (ATSDR, 2004). Elevated copper levels in drinking water may increase lead levels when lead solder joints, lead service lines, or brass fixtures are present in plumbing material. It is advised to test for lead when testing for copper levels in drinking water as lead and copper enter drinking water under similar conditions (Lee, 2008).

PEX (polyethylene cross linked) is another type of plumbing material often used in residential plumbing. This material is used to make flexible plastic pipes. A different plumbing design characterized by individual pipe lengths is required for every fixture. The main advantage of PEX is the lack of joints requiring soldering, which decreases the probability of pipe failures. On the other hand, PEX plumbing has raised some concerns regarding possible leaching of MTBE (methyl tertiary butyl ether), ETBE (Ethyl tert-butyl ether), and benzene into drinking water. Other concerns are the negative health impacts associated with PEX's reaction with chlorine, increased water odors (Durand & Dietrich, 2007), the material's ability to withstand fire, and its final disposal (PRNews Wire, 2004). In addition, PEX may become stiff in cold weather, which makes faulty pipe repairs more difficult. PEX use has been approved in all U.S. states (Toolbase News, 2008), and has met all health standards set by NSF/ANSI-61 for potable water supply (NSF, 2008).

CPVC plumbing material is also employed in residential plumbing, but presents many concerns. For example, it can become brittle when exposed to sunlight for an extended period of time, and presents possible negative health effects from microbial growth in the inner pipe. Other possible concerns are cracking in the event of an earthquake, plastic water taste, and melting in the event of fire. The solvents used to join fittings and pipe lengths may contain volatile organic compounds (VOCs), requiring proper ventilation during installation, and causing unpleasant odor problems. However, CPVC by itself has a low odor potential (Heim & Dietrich, 2007).

The last plumbing material type is stainless steel, which is often used in industrial applications. Stainless steel provides excellent resistance to corrosion, due to the presence of 18% chromium and 8% nickel (Roberge, 2000). The stainless steel material is, however, expensive. Due to the cost, its use is limited to specialized industries for conveying chemicals or other similar applications (Lee, 2008). A concern with stainless steel pipes is the possibility of leaching chromium into drinking water; however, all U.S. states have approved stainless steel use (NSF, 2008; Roberge, 2000).

The economically sustainable optimal replacement time for home plumbing systems is about 22 years after installation (Loganathan & Lee, 2005). The estimate, however, is dependent on the source and type of the employed data (Loganathan and & Lee, 2005). When it is time to replace the plumbing system, the homeowners have to decide on a plumbing system to be installed in their homes. For example, several homeowners in a Southeastern Community in the U.S. replaced their copper pipes with PEX. According to them, PEX is less labor intensive in case of installation, resistant against corrosion, and less expensive compared to copper (Plumbing and Mechanical Magazine, 2007).

However, plumbing material replacement or repairs can be rather expensive. Farooqi and Lee (2005) conducted a survey of plumbers in the U.S. and found plumbers to charge their work on an hourly basis. The cost per hour varied from $45 to $75, and the total cost of plumbing material replacement ranged from $3,654 for PEX to $5,680 for copper pipes (Farooqi & Lee, 2005). Furthermore, fixing dry wall, floor tiles, or ceilings affected by plumbing material replacement is not part of the services provided by the plumber, and homeowners have to hire a general contractor to fix the water related damage. Kleczyk and Bosch (2008) have reported the additional costs associated with damage from pipe failures reaching as much as $25,000, and forcing household members to reside in temporary housing during the repair period.

On the other hand, Scardina et al. (2007) (also discussed in Kleczyk et al. 2006) investigated the willingness-to-pay for a leak-free plumbing material in households located in different parts of the U.S., such as Florida and California. They found 47% of all respondents willing to pay a positive amount to ensure that material would remain leak-free, 27% unwilling to pay any amount to ensure that material would remain leak-free, and 25% unsure about how much they would be willing to pay. About 6% of respondents were willing to pay at least $4,000 to ensure that material would remain leak free for 50 years. This amount is 10 times the suggested base material cost for re-plumbing a 2,000 square foot house. The mean willingness-to-pay estimate was higher for respondents with leaks compared to respondents who had no leaks, constituting $1,130 and $1,007 respectively. Finally, 45% of respondents with leaks and 41% of respondents without leaks were not willing to pay for leak-free plumbing materials (Dietrich et al., 2006; Kleczyk et al., 2006; Scardina et al. 2007).

3. Survey design and distribution

The Southeastern Community located in the United States of America was established in 1980s, and spans over 4,700 acres. There are about 3,300 homes, including condos and apartments, with 6,600 residents in total. Most of the resident population is retired, so the community is rather a homogenous group. The first incidents of pinhole leaks were reported in 2001.

In August 2007, a questionnaire was sent to 1600 households in the Southeastern Community. The community's Property Owners' Association provided a list of the residents' names and addresses, and the sample was randomly selected from this list. Members of the Assocaition's Board reviewed the survey questions. The Association encouraged participation of community residents in the study. The survey was distributed following the Dillman technique of mail surveying, which included mailing a questionnaire with postage-paid return envelope, sending a reminder card, and mailing a second copy of the survey to nonresponders (Dillman, 1978).

In 2007, two surveys were conducted by the Virginia Tech researchers to learn about the home plumbing issues and the preventive measures taken against future corrosion incidences. The first survey acquired information on the incidents of pinhole leaks in the residential area, the adoption rate of preventive measures against corrosion, the homeowners' preferences for corrosion risk, and the costs associated with a leak free environment. The second survey elicited preferences for three hypothetical plumbing materials with different attribute levels. The sample of respondents was based on the first Southeastern Community survey respondents, who were willing to participate in the follow-up questionnaire.

A follow-up survey was administered in October 2007 to learn household preferences for home plumbing materials. The follow-up survey was sent 363 Southeastern Community householders who responded to the first survey, and who agreed to participate in future surveys. The respondents were exposed to attributes of three hypothetical to them plumbing system materials, which were left unnamed to avoid a survey exposure bias[2]. The materials represented in the questionnaire were copper, plastic, and epoxy coating. Materials were left unnamed, because most homeowners were familiar with at least one material type (copper,

[2] Survey Exposure Bias represents the ability to skew respondents' responses, based on the information either presented during the study or known prior to the study (Champ et al., 2003).

plastic, or epoxy coating), and positive or negative experiences with these materials could have influenced their responses. The questions included two stimuli, which are compared simultaneously. Each respondent rated each of the two alternatives on a scale from 1 to 9. The scale value of 1 indicates the plumbing material is not preferred, while 9 indicates an extremely preferred plumbing system. The material attributes are listed in Table 1.

Attributes	Material A (Epoxy Coating[a])	Material B (Plastic[a])	Material C (Copper[a])
Corrosion Resistance	Corrosion proof	Same as material A	Some risk of corrosion
Taste / Odor	Compounds released from this material in drinking water plumbing may give a chemical or solvent taste or odor to the water.	Same as material A	Compounds released from this material in drinking water plumbing may give a bitter or metallic taste or odor to the water.
Health Effects	Material meets EPA Standards. There is a very small chance that compounds from this plumbing material that are released into drinking water may lead to microbial growth in water. Microbial growth may cause severe illness.	Same as material A	Material meets EPA Standards. There is a very small chance that compounds from this plumbing material that are released into drinking water may cause vomiting, diarrhea, stomach cramps, and nausea.
Convenience of Installation	No need to tear into the wall and/or floor. Installation takes around 4 days.	Need to tear into some sections of wall for installation. Installation takes 5-6 days.	Need to tear into the wall and/or floor to replace the existing system. 7-9 days required for installation.
Proven performance in market	Less than 10 years in the market	Less than 20 years in the market	More than 50 years in the market
Cost (labor + material)	$9,000 ~ 14,000 depending on the size of house	$6,500 ~ 13,000 depending on the size of house	$9,000 ~ 16,000 depending on the size of house
Warranty	Warranty is 15 years for the material.	Warranty is 10 years for the material.	A 50 year manufacturer's warranty applies. Some exceptions apply (e.g. warranty reduces to one year if compounds in water corrode pipes).

[a]Names of the plumbing materials were not revealed to the study participants

Table 1. Description of plumbing materials.

4. Empirical analysis

The empirical analysis of the Southeastern Community home plumbing data includes several econometric and statistical techniques. The first survey data analysis uses simple descriptive statistics, such as mean (average values), percentages (percent distribution across all responses), and total sums, in order to provide a summary view of the home plumbing issues faced by the Southeastern Community. These issues include the frequency of pipe failure, the location of the failure in the plumbing system, the costs and time associated with fixing pipe failures, and the preventive measure taken to avoid incidences in the future. The analysis preferred plumbing materials concentrates on estimating the household preferences for plumbing types based on the follow-up survey of the Southeastern Community. The data estimation process employs the Ordered Logit regressions, based on which the household preferences for plumbing materials are derived. The paragraphs presented below describe the econometric models in more detail.

4.1 Ordered logit model description

The second Southeastern Community survey data analysis employs the Conjoint Analysis (CA) methodology to analyze the preferences for plumbing materials. This type of analysis includes eliciting the preferred good / service choices based on the presented information / stimuli. Utility Maximization Theory is usually employed to guide the process, design, and analysis of the CA studies, and involves making a choice that yields the greatest satisfaction to the respondents, otherwise known as utility, based on their available financial resources. As a result, the preference maximization problem is defined mathematically, as maximization of a utility function based on a specified financial resource constraint (Varian, 1992):

$$\text{Maximize utility function: } u(x) \quad (1)$$

$$\text{Subject to: } px \leq m, \text{ where } x \text{ is in } X, \quad (2)$$

where $u(x)$ represents the utility function, and $px \leq m$ represents the financial resource constraint, with m being the fixed amount of money available to households (Champ et al., 2003).

In this chapter, a household faces a choice among three plumbing material alternatives. The utility (satisfaction) obtained from choosing a plumbing material, i, by the nth household is U_{ni}. The decision maker chooses the option yielding the highest level of utility, which implies the following behavioral model: $U_{ni} > U_{nj}$, where $i \neq j$. The level of utility is not observed by the researcher, but the attributes of the plumbing alternatives (x_{ni}) in the choice set are observed, as well as the socioeconomic characteristics of the decision maker (z_n). Based on the known variables, a representative utility function can be specified as: $V_{ni} = V(x_{ni}, z_n)$ for all alternatives (Train, 2003).

For this exercise, each respondent pair-wise rated the preferred plumbing material option. The rating scale ranges from 1 to 9, with 1 indicating a not preferred plumbing material option, and 9 indicating the most preferred option. The plumbing material rating exercise is based on the utility-maximizing behavior, as higher plumbing material rating results in an increased level of utility, and therefore, a higher preference level for a given alternative. The rating scale questions require individuals to make judgements about the magnitude of utility associated with plumbing material profiles. These plumbing material evaluations directly transform utility levels into a rating scale. As a result, an employment of rating models in which the rating value for each profile is regressed on a vector of attribute levels is justified (Champ et al., 2003).

To analyze the CA data, an Ordered Logit regression is employed. The Ordered Logit is based upon the idea of the cumulative logit, which relies on the cumulative probability. The cumulative probability CP_{nl} is the probability that the nth individual is in the l^{th} or higher plumbing material valuation category:

$$CP_{nl} = \text{probability } (R_l \leq l) = \sum_{(l=1 \text{ to } L)} \text{probability}(R_l = L). \tag{3}$$

The cumulative probability is transformed into the cumulative logit:

$$\text{logit } CP_{nl} = \log(CP_{nl}(1 - CP_{nl})). \tag{4}$$

The ordered logit simply models the cumulative logit as a linear function of independent variables:

$$\text{logit } CP_{nl} = \alpha_l - \boldsymbol{\beta} \mathbf{x_n}. \tag{5}$$

There is a different intercept for each level of the cumulative logit, but $\boldsymbol{\beta}$ remains constant across rating categories. In addition, the product of $\boldsymbol{\beta}$ and the independent variable, $\mathbf{x_n}$, is subtracted rather than added in the model. As a result, each α_l indicates the logit of the odds of being equal to or less than category l for the baseline group (when all independent variables are zero). The $\boldsymbol{\beta}$ represents the increase in the log-odds of being higher than category l as the independent variable increases by one-unit (Edner, 2005).

The empirical Ordered Logit model is represented by the following regression:

$$R = \alpha_l - \sum_{(n=1\ldots N)} \sum_{(i \in R)} [\sum_{(k=1 \text{ to } K)} \beta_k x_{jkn} + \beta_p p_{jkn}] + e \tag{6}$$

where R represents the ordered rating scale (1-9), where β_k is the preference parameter associated with the plumbing material attributes , x_{jkn} are the plumbing material attributes in profile j for individual n, β_p is the parameter on profile cost, p_{jkn} is the cost attribute for profile j and e is the error term (Champ et al., 2003).

Although attributes of the plumbing materials vary over alternatives; the characteristics of each household do not differ over the alternatives. As a result, the socioeconomic variables need to enter the model estimation to leverage and explain the differences in utility levels between corrosion preventive options. These characteristics can enter the model through interaction with the plumbing material attributes (Train, 2003).

5. Home plumbing corrosion issues

5.1 Pinhole leak awareness and Incidents

A total of 1,047 survey responses were received, a 65% response rate. Seventy-six percent of respondents reported being very aware of pinhole leaks, 21% said they were somewhat aware of the problem, and 2% said they were unaware of the problem. Nineteen percent reported learning about pinhole problems through their own experience, 65% heard through a neighbor or friend, 48% heard about pinhole leaks through the media, and 42% reported hearing of the problem through the property management.

Two hundred twelve respondents (20%) reported incidents of pinhole leaks in drinking water pipes in their current homes; 780 respondents (74%) reported no incidents of pinhole leaks; and 32 respondents (3%) were not sure of any incidents. One hundred twenty eight respondents (60% percent of the respondents with leaks) had 1 or 2 leaks, 47 respondents (22%) had 3 or 4 leaks, 17 (8%) had 5 or 6 leaks, and 15 (7%) had 7 or more incidents. Over 90% of the leaks had occurred since the year 2000. Of 212 respondents with pinhole leaks, 151 (71%) stated that their first pinhole leak occurred since 2004, and 44 (21%) stated that their first leak occurred between 2000 and 2003.

Respondents with pinhole leaks had somewhat older homes compared to respondents without leaks (Table 2). Fifty-three percent of respondents without leaks lived in homes built since 2000 compared to 4% of respondents with leaks. Five percent of respondents without leaks lived in homes built before 1990 compared to 23% of respondents with leaks.

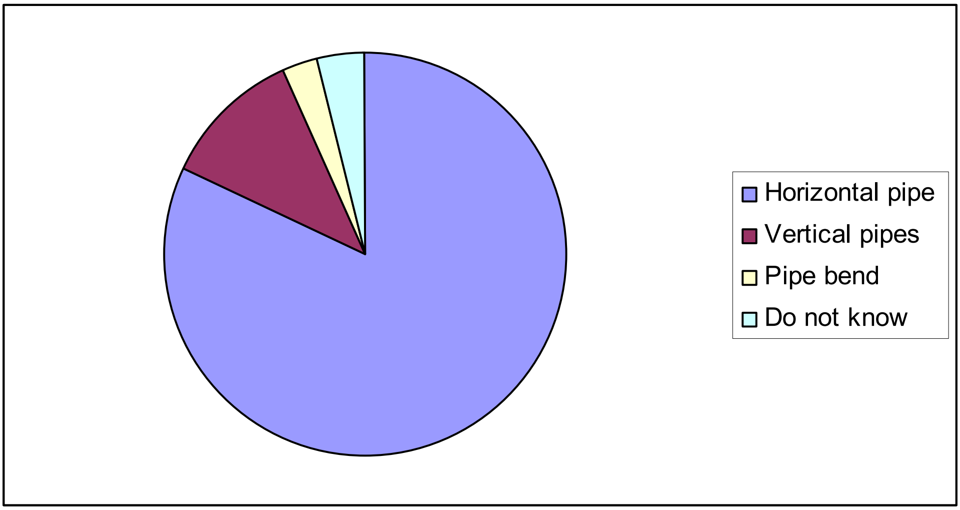
	Respondents without leaks		Respondents with leaks	
Year house was built	Number	Percent[a]	Number	Percent[b]
Since 2000	441	53	9	4
1995 to 1999	240	29	76	36
1990 to 1994	102	12	75	36
Before 1990	39	5	49	23
Do not know	1	0	2	1
Missing/not reported	12	1	1	0
Total	835	100	212	100

[a]Percent = number divided by total number of respondents without leaks (835).
[b]Percent = number divided by total number of respondents with leaks (212).

Table 2. Year house was built.

Most respondents with leaks had leaks in horizontal pipes, while fewer had leaks in vertical pipes or pipe bends (Figure 1). Most leaks were in the finished or unfinished basement followed by the crawl space and first floor, respectively.

Pinhole leaks occurred in cold water pipes in 138 cases, in both cold and hot water pipes in 14 of the cases, and in hot water pipes only in 33 cases (Table 3). Twenty respondents were not aware of the type of water pipes where leaks occurred.



[a]Multiple choices per respondent were accepted. Percent = number reported divided by the total number of respondents with leaks (212).

Fig. 1. Pinhole leaks by type of pipe.

Type of pipe	Number of observations	Percent
Cold water pipes	138	65
Hot water pipes	33	16
Both	14	7
Do not know	20	9
Missing/not reported	7	3
Total	212	100

Table 3. Pinhole leaks occurring in cold or hot water pipes.

5.2 Pinhole leak repairs and repair costs

Seventy-seven respondents repaired the leak using a clamp (Table 4). In some cases, a clamp was used initially while the leaking section or all plumbing was replaced for later leaks. One hundred thirty-three respondents repaired the leak by replacing the leaking pipe section. Copper was most often used for repairing leaking sections. Fifty respondents repaired the leak by replumbing the entire house. PEX was most often used for replumbing. Nine respondents applied epoxy coating to their existing plumbing systems.

More than 60% of respondents with leaks spent less than 20 hours dealing with pinhole leaks while more than 30% spent 21 or more hours. Twenty percent spent more than 40 hours dealing with pinhole leaks.

Twenty-nine percent of respondents with leaks reported that the expense of repairing pinhole leaks was less than $100; while 30% reported expenses between $100 and $500; and 37% reported more than $500 in expenses for pinhole leak repairs (Table 5). Seven respondents reported more than $10,000 in costs of repairs.

Repair method	Number of observations	Percent[a]
Clamp over leak	77	7
Replaced leaking pipe section with copper	75	35
Replaced leaking pipe section with CPVC	5	2
Replaced leaking pipe section with PEX	7	3
Replaced leaking pipe section-material not specified	46	22
Applied epoxy coating to all plumbing	9	4
Replumbed with copper	5	2
Replumbed with CPVC	4	2
Replumbed with PEX	32	15
Replumbed-material not specified	9	4
Other	7	1
Don't know	3	1
Total	279	129

[a]Multiple choices per respondent were accepted. Percent = number reported divided by the total number of respondents with leaks (212).

Table 4. Method of leak repair.

Amount	Number of observations	Percent[a]
Less than $100	61	29
$100 to $500	64	30
$501 to $1,000	14	7
$1,001 to $3,000	11	5
$3,001 to $5,000	20	9
$5,001 to $10,000	28	13
$10,001 to $20,000	6	3
More than $20,000	1	0
Do not know	3	1
Missing/not reported	4	2
Total	212	99

[a]Numbers do not sum to 100 due to rounding.

Table 5. Costs of repairing pinhole leaks.

In addition to the expense of repairing leaks, 92% of respondents with leaks reported having to repair property damage caused by leaks. Forty percent of respondents with damage reported less than $100 of damage, while 49% had over $100 in damage. Twelve respondents had over $5,000 in property damage. Thirty-six percent of respondents reporting leaks found the experience of pinhole leaks very stressful, and 46% found it somewhat stressful. Thirteen percent experienced little or no stress.

5.3 Pinhole prevention and water treatment devices

Thirty-five percent of respondents with leaks and 20% of respondents without leaks use some type of pinhole leak prevention strategy (Table 6). The most common strategy among those with leaks is preventive replumbing, which was used by 13% of those with leaks. Water softener / conditioner was the most common strategy used by those without leaks, which was used by 9% of those respondents.

Sixty-seven percent of respondents use some type of water treatment for purposes other than pinhole leak prevention (Table 7). The most common treatment was a refrigerator filter, used by 63%. Thirty-two percent of respondents reported that they purchase drinking water. The most common reasons given for using water treatment devices are to improve taste or smell of drinking water (mentioned by 45% of respondents), and to improve safety of drinking water (mentioned by 33% of respondents).

	Respondents with pinhole leaks[a]		Respondents without pinhole leaks[b]	
	Number	Percent	Number	Percent
Preventive replumbing	28	13	16	2
Preventive epoxy injection	8	4	4	0
Phosphate injection	12	6	26	3
Water softener/water conditioner	11	5	79	9
Copper Knight	5	2	12	1
Other	19	9	64	8
None used	134	63	644	77
Missing/not reported	4	2	29	3
Total	295	139	874	105

[a]Multiple choices per respondent were accepted. Percent = number reported divided by the total number of respondents with leaks (212).
[b]Percent = number reported divided by the total number of respondents without leaks (835).

Table 6. Use of pinhole leak prevention devices.

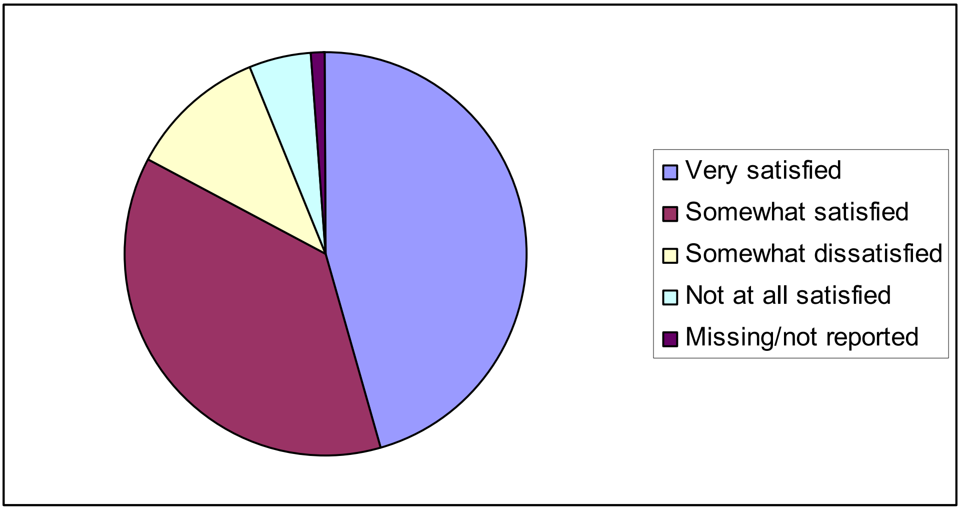
5.4 Concerns about water safety and quality

Eighty-two percent of respondents were somewhat or very satisfied with home drinking water quality (Figure 2). Only 5% of respondents were not at all satisfied with water quality. Problems with water quality most frequently mentioned were related to taste particularly chlorine. Respondents varied in concern about future pinhole leaks. Forty percent were somewhat or very concerned, while 55% were not very or not at all concerned.

	Number	Percent[a]
Filter for entire home	133	16
Refrigerator filter	523	63
Water softener/water conditioner	66	8
Pitcher or bottle to filter water	136	16
Purchased drinking water	265	32
Filter on faucet or under kitchen sink	117	14
Ultra violet (UV) system	2	0
Other	25	3
None used	249	30
Missing/not reported	19	2
Total	1,535	184

[a]Multiple choices per respondent were accepted. Percent = number reported divided by the total number of respondents (1,047).

Table 7. Use of water treatment for purposes other than corrosion prevention.



[a]Totals do not sum to 100 due to rounding.

Fig. 2. Satisfaction with home drinking water quality.

6. Household preferences for plumbing material

6.1 Summary of descriptive results

Every respondent to the first Southeastern Community survey was asked to participate in the follow-up survey. Three hundred sixty three respondents agreed to participate, and 245 responded to the follow-up survey. Each respondent evaluated three Conjoint Analysis scenarios describing a set of two plumbing materials (Material A= epoxy coating, Material B = plastic, and Material C = copper that were blinded to avoid survey exposure bias) and answered questions comparing material attributes. Each plumbing material was described by the following attributes: corrosion resistance, taste and odor, health effects, convenience of installation, proven performance on the market, plumbing material cost, and warranty length. Table 1 presents the plumbing material attributes in more detail.

Each respondent was asked to compare a pair of plumbing materials, and evaluate each plumbing material based on a 1-9 preference scale. For example, Material A might be rated as 6, while Material B might be rated as 1. The 1-9 preference scale had a verbal preference assigned to each categorical value. Preference values of 1, 3, 5, 7, and 9 were assigned to 'Not Preferred', 'Moderately Preferred', 'Strongly Preferred', 'Very Strongly Preferred', and 'Extremely Preferred', respectively. Two hundred thirty respondents fully answered all questions, and each viewed three pairs of two plumbing materials resulting in 1,380 preference responses.

As each presented plumbing material had all attributes listed, and there was no randomization of attribute levels across the plumbing materials, the preference score was easily identified with the preferred plumbing material by comparing the attribute levels with the plumbing material descriptions. All preference responses to each plumbing material were then summed, and the plumbing material with the highest number of 'Extremely Preferred' responses and with lowest number of 'Not Preferred' responses was selected as the most preferred plumbing material. Table 8 presents the descriptive statistical summary of preference valuation break down of the 1,380 responses for plumbing materials. Material C (copper) is the least preferred type of plumbing material (211 not preferred responses), while Material A (epoxy coating) is the most preferred material among homeowners (39 extremely preferred responses).

	Preference Response Value				
Plumbing Material	Not Preferred	Moderately Preferred	Strongly Preferred	Very Strongly Preferred	Extremely Preferred
Material A	103	134	99	85	39
Material B	148	151	85	56	20
Material C	211	156	56	31	8
Total	460	441	240	172	67

Table 8. Preference valuation of plumbing materials.

In addition to evaluating three sets of two plumbing material scenarios, each respondent selected the most preferred plumbing material across all three materials displayed at the same time. Table 9 presents that Material A (epoxy coating) is chosen as the preferred plumbing material by more than 50% of respondents. Material C (copper) is the least often chosen as the preferred plumbing material (17.8%). These two separate measures yield the same result of Material A being the most preferred plumbing material across the three alternatives.

Plumbing Material	Frequency	Percent
Material A	116	50.4
Material B	48	20.8
Material C	41	17.8
Neither	4	1.7
Missing	22	9.7
Total	230	100

Table 9. Plumbing material chosen as most preferred.

6.2 Empirical analysis results

6.2.1 Order logit model without socioeconomics variables

For this part of the analysis, the Ordered Logit regression is utilized in the plumbing material estimation of preferences and is estimated at the aggregate response level. The aggregate level analysis implies that average value coefficients are estimated for the participating sample of respondents.

The analysis provides information on the preferences of homeowners for plumbing materials, and the attributes that drive their decision, when making purchasing decision with regards to the type of home plumbing system. Each respondent evaluated a set of two plumbing material portfolios at one time for a total of six portfolios using the valuation metrics 1-9 described earlier. Each of the plumbing materials has a set of attributes described in Table 1. Each material attribute level is employed as the independent variable in the material preference analysis. They are coded as dummy variables taking a value of 1 when that plumbing material characteristic is a part of the product portfolio and zero otherwise. Finally, the socioeconomic characteristics (reported in the first survey) are also included in the Ordered Logit model. These characteristics represent household home value (continuous variables), age of the house (continuous variable), plumbing material type (dummy variable), pinhole leak occurrences in the past (dummy variable), and respondent's previous cost of plumbing material repairs and replacement (continuous variable).[3]

The first step in evaluating the results of the Ordered Logit model is to review the model performance / fitting criteria. The model fitting information indicates the parameters for which the model-fit is calculated. There are four variables that evaluate the goodness of fit: Chi-square statistics[4], p-value[5], log-likelihood value[6], and R-square[7]. The model fitting

[3] Variables for race, education level, and gender were not included in the model, as little variation in these characteristics was observed for the sample of respondents.

[4] Chi-square Test establishes whether or not an observed frequency distribution differs from a theoretical distribution (Aaron, 2005).

[5] P-value is the probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the null hypothesis is true (Aaron, 2005).

[6] Log-likelihood Test compares the fit of two models, one of which (the null model) is a special case of the other (the alternative model) (Aaron, 2005).

[7] R-square represents the proportion of variability in a data set that is accounted for by the statistical model (Aaron, 2005).

information presents that the Chi-square statistic is 114.136 with a p-value of 0.000, and a log-likelihood value of 182.641, which implies the existence of a relationship between the independent variables (plumbing material attributes) and the dependent variable (plumbing material selection) is supported. The goodness-of-fit measure is also employed, and the Nagelkerke's R-square is 0.084, which implies that 8% of variation in the dependent variable is explained by the variation in the independent variables.

In evaluating the Ordered Logit model, threshold represents the response variable in the regression. A different intercept is provided for the different levels of the cumulative logit model. The beta coefficient of the independent variables does not change, and the value of each is subtracted from the intercept. Each threshold level indicates the logit of the odds of being equal to or less than the baseline category when all independent variables are zero (Aaron, 2005). The baseline group is set to 'Extremely Preferred'. The beta estimate represents that a one unit increase in the independent variable increases / decreases the log-odds of being higher than a specific preferred valuation category. Because the beta coefficient is not indexed by each category, a one unit increase affects the log-odds the same regardless of which threshold value is considered (Aaron, 2005).

As represented in Table 10, the regression estimates reveal that when compared to the baseline category ('Extremely Preferred'), the categories 'Moderately Preferred', 'Strongly Preferred', and 'Very Strongly Preferred' have higher threshold estimates. A category 'Not Preferred' has a statistically insignificant negative coefficient estimate. Since the estimate is not statistically significant at the 95% confidence interval, it is not included in comparison analysis between the categories.

The threshold values are also evaluated. These values inform the expected cumulative distribution of categorical preference values for individuals with the independent variables set to zero (Aaron, 2005). This threshold represents a natural tendency for all the responses to all the scenarios presented to respondents when the independent variables are suppressed. When these coefficients are exponentiated, the cumulative odds for each category are obtained (Table 12). By employing the following equation, (odds /(1+odds)), the cumulative probabilities are computed (Aaron, 2005). Table 10 represents the odds ratios and cumulative probabilities (columns 3 and 4 in Table 10). For example, the 'Moderately Preferred" category is 3.7 times more likely to be selected by the respondent compared to the 'Extremely Preferred' category when all independent variables are set to zero.

The independent variable coefficient estimates are statistically significant only for two attribute levels: risk of corrosion variable represented by 'corrosion proof' attribute level and convenience of installation represented by 'no need to tear into the wall and/or floor. Installation takes around 4 days' (Table 10). Other independent variables were considered redundant in the model estimation. The independent variable coefficients represent how the log-odds of these thresholds increase / decrease with one unit of the independent variable. The positive value indicates that one unit of independent variable increases the odds of being in a higher category (Aaron, 2005). For example, the 'corrosion proof' attribute level increases the odds of choosing a higher preference category by 0.654 compared to the independent variable represented by 'some risk of corrosion' attribute level. 'Installation of plumbing material taking about 4 days' increases the odds of choosing a higher preference category by 0.559 compared to 'the installation taking between 7 and 9 days.'

Besides evaluating the directional impact of the independent variables on the preference level of the households, the impact of the statistically significant independent variables on the preference category is evaluated for all three plumbing materials. As the attribute levels describing each of the three hypothetical materials are known, the regression results can be organized by plumbing materials. For example, Material A is described by attribute level called 'corrosion proof' as well as 'installation takes around 4 days'. The coefficient estimates for the statistically significant attribute levels are employed to compute preference valuation categories for each material type. In case of the Material A (epoxy coating) computation of the preference valuation category called 'Moderately Preferred', the following represents the estimate computation: 1.315 - 0.654 - 0.559= 0.102, where 1.315 is the moderately preferred coefficient, 0.654 is 'the corrosion proof' coefficient, and 0.559 is 'the convenience of installation' coefficient; and the odds ratio computation: exp(0.102) = 1.107.

Variable Name	Coefficient Estimate[b]	Standard Error[c]	Wald-Stats[d]	P-Value[d]
Threshold Values (For All Independent Variables Set to Zero)				
Not Preferred	-0.096	0.108	0.790	0.374
Moderately Preferred	1.315	0.115	131.554	0.000
Strongly Preferred	2.289	0.125	333.413	0.000
Very Strongly Preferred	3.742	0.164	521.510	0.000
Independent Variables (Variables that Improve Overall Model Significance)[e]				
1) Corrosion proof	0.654	0.143	20.943	0.000
2) No need to tear into some sections of wall for installation. Installation takes around 4 days.	0.559	0.119	22.016	0.000

[a]The number of observations included in the model is 1086. Independent variables take form of dummy variables with value of one when the characteristic was present in the plumbing material profile and zero otherwise. To avoid a dummy variable trap, one of the attribute levels was excluded from the analysis. The omitted characteristics represent Material C (copper) descriptions.
[b] Coefficient estimates show how much increase in the likelihood of being in a higher category results from a one unit increase in the independent variable.
[c] Standard error represents the variation of the estimate.
d Wald statistics and p-value represent the significance level.
[e] Model Statistics: Log-likelihood value is 182.641 with chi-square of 114.136 and p-value of 0.000; Nagelkerke's R-square is 0.084.

Table 10. Ordered logit regression estimates with categorical answers (dependent variable represents the plumbing material valuation and the independent variables represent the plumbing material attributes (without socioeconomic variables))[a].

When further investigating the Ordered Logit results, the coefficient for each preference category in combination with the coefficients for each independent variable can be expressed as marginal probability estimates to provide a greater insight into the preferred plumbing material (Table 11). Based on the marginal distribution of the probability estimates, Material A has a larger probability estimate for 'Strongly Preferred' to 'Extremely Preferred' category preference. On the other hand, Material C has a higher probability estimates for categories 'Not Preferred' and 'Moderately Preferred'. All three materials have the highest frequency of estimates falling into 'Not Preferred' and 'Moderately Preferred' categories. Based on the overall results, Material A (epoxy coating) is the most preferred material followed by Material B (plastic). Material C (copper) is the least preferred plumbing material.

	Material A	Material B	Material C
	Coefficient Estimates[a]		
Not Preferred	-1.309	-0.750	-0.096
Moderately Preferred	0.102	0.661	1.315
Strongly Preferred	1.076	1.635	2.289
Very Strongly Preferred	2.529	3.088	3.742
Extremely Preferred			
	Odds Ratio Estimates		
Not Preferred	0.270	0.472	0.908
Moderately Preferred	1.107	1.937	3.725
Strongly Preferred	2.933	5.129	9.865
Very Strongly Preferred	12.541	21.933	42.182
Extremely Preferred			
	Marginal Probability Estimates Distribution		
Not Preferred	0.213	0.321	0.476
Moderately Preferred	0.313	0.339	0.312
Strongly Preferred	0.220	0.177	0.120
Very Strongly Preferred	0.180	0.120	0.069
Extremely Preferred	0.074	0.044	0.023

[a]Coefficient estimates are built up from the statistically significant estimates for the attribute levels and threshold values. Coefficients are compared to the base "Extremely Preferred" level.

Table 11. Ordered logit regression results' analysis by plumbing material type (dependent variable represents the plumbing material valuation and the independent variables represent the plumbing material attributes (no socioeconomic variables)).

6.2.2 Order logit model with socioeconomics variables

The second specification of the Ordered Logit model includes the socioeconomic variables alongside of the attributes for plumbing material. As the socioeconomic characteristics do not vary for a given respondent, they should be interacted with the attributes levels of each attribute. As the total number of respondents is rather small (230), there are not enough degrees of freedom to include all interaction variables between the attribute levels and the household characteristics. As a result, the Ordered Logit model was first estimated with socioeconomic variables entering one at a time to measure the impact of household characteristics on the plumbing material preferences. The statistically significant interaction variables were then included in the final model estimation.

When the socioeconomic variables were entered in the Ordered Logit model one at a time, 'corrosion proof' as well as 'installation takes about 4 days' were the two attribute levels appearing statistically significant in many of the model specifications. The coefficient value for corrosion attribute varied from 0.651 to 1.450, and the convenience of installation coefficient varied from 0.554 to 0.754. The only statistically significant interaction effect was observed between attribute level of 'corrosion proof' and respondent's 'previous cost of plumbing materials repairs or replacement' (coefficient estimate = 0.00001; standard error = 0.00000; Wald-statistic[8] = 15.773; p-value = 0.000). This interaction effect was entered into the final model estimation alongside of other plumbing material attributes.

The threshold values, which inform the expected cumulative distribution of categorical preference values for individuals with the independent variables set to zero, are evaluated (Aaron, 2005). Table 12 represents the odds ratios and probabilities. For example, the 'Moderately Preferred" category is 3.67 times more likely to be selected by the respondent than the 'Extremely Preferred' category when all independent variables are set to zero. On the other hand, the 'Not Preferred' category is only 0.86 times as likely to occur compared to the baseline category when no independent variables are considered.

Based on Table 12, the independent variable coefficient estimates are statistically significant only for two attribute levels: 'corrosion proof' and 'installation takes about 4 days'. For example, the 'corrosion proof' variable increases the odds by 1.145 of choosing a higher preference category compared to the variable set at 'some risk of corrosion'. 'Installation of plumbing material taking about 4 days' increases the odds of choosing a higher preference category by 0.575 compared to 'the installation taking between 7 and 9 days'. The only socioeconomic variable entered into the regression is the respondent's previous cost of plumbing repairs and/or material fixing or replacement and is statistically significant when interacted with corrosion proof attribute level. The joint coefficient is 1.197 (1.145+0.0001*$522[9]) and is statistically significant at 5% significance level[10]. This coefficient value further implies that the interaction variable increases the odds by 1.197 of choosing a higher preference category compared to the variable set at 'some risk of corrosion'. This finding can be explained as households, who have accrued cost of plumbing material repairs in the past, value the 'corrosion proof' attribute level more compared to the 'some risk of corrosion' attribute level. Plumbing material with low corrosion risk would imply decrease in the future costs of plumbing material repairs.

As in the previous version of the Ordered Logit model, effects of statistically significant independent variables on the preference category for all three plumbing materials are evaluated. The statistically significant attribute levels were computed together with the thresholds levels by plumbing material into odds ratios and probability values. As attribute levels describing each of the three hypothetical materials are known, the regression results can be organized by plumbing materials. For example, Material A is described by attribute

[8] Wald Test is used to test the true value of the parameter based on the sample estimate (Aaron, 2005).
[9] $522 is the mean cost value of the previous cost spent on plumbing material repairs and replacement.
[10] Cost of Plumbing Material Fixing or Replacement * Corrosion Proof: Wald statistic = 5.684 and p-value = 0.020.

level called 'corrosion proof' and 'installation takes about 4 days'. The coefficient estimates for the statistically significant attribute levels are employed in the material based preference category computation. In case of Material A (epoxy coating) the computation for preference valuation category of 'Moderately Preferred', the following represents the estimate computation: 1.300- 1.145- 0.575 -0.0001*$522 = -0.472; and the odds ratio computation: exp(-0.472) = 0.624 (Table 15).

Variable Name	Coefficient Estimate[b]	Standard Error[c]	Wald-Stats[d]	P-Value[d]
Threshold Values (For All Independent Variables Set to Zero)				
Not Preferred	-0.147	0.089	2.705	0.100
Moderately Preferred	1.300	0.098	176.801	0.000
Strongly Preferred	2.317	0.114	415.544	0.000
Very Strongly Preferred	3.790	0.164	532.389	0.000
Independent Variables for Model Specification with Socioeconomic Variable Interactions[e and f]				
Corrosion Proof	1.145	0.502	5.190	0.023
Need to tear into some sections of wall for installation. Installation takes around 4 days.	0.575	0.134	18.331	0.000
Respondent's previous cost of plumbing repairs and/or replacement * Corrosion Proof	0.0001	0.00006	4.644	0.031

[a] The number of observations included in the model is 1072. Independent variables take form of dummy variables with value of one when the characteristic was present in the plumbing material profile and zero otherwise. To avoid a dummy variable trap, one of the attribute levels was excluded from the analysis. The omitted characteristics represent Material C (copper) descriptions.
[b] Coefficient estimates show how much increase in the likelihood of being in a higher category results from a one unit increase in the independent variable.
[c] Standard error represents the variation of the estimate.
[d] Wald statistics and p-value represent the significance level.
[e] Model Statistics: Log-likelihood value is 1565.522 with chi-square of 119.384 and p-value of 0.000; Nagelkerke's R-square is 0.101.

Table 12. Ordered logit regression estimates with categorical answers (dependent variable represents the plumbing material valuation and the independent variables represent the plumbing material attributes and socioeconomic variables interacted with attribute levels)[a].

As presented in Table 13, Material A has the lowest values of estimates for all preference categories, compared to Materials B and C. Material C has the highest values of preference valuation. Threshold values with smaller absolute values imply smaller differences between preference valuation categories and the base category in the likelihood of that preference category being selected. For example, Material B has a smaller absolute threshold value compared to Material A for the "Not Preferred" category, implying a smaller difference between 'Not Preferred' and 'Extremely Preferred' for Material B (-1.344) compared to Material A (-1.919).

Material C has the highest values of odds ratios for each preference category while Material A has the lowest. The odds ratios that present the likelihood of a preference category being selected are compared to the base category. For example, the category 'Strongly Preferred' is 10.145 times as likely to be selected as the base category for Material C while for Material A it is only 1.724 times as likely. A lower odds ratio for each preference category is more preferred, as it implies that the 'Extremely Preferred' category has a higher chance of being chosen relative to other categories. This finding implies that Material A is a more preferred home plumbing choice for households.

Following further analysis of the marginal distribution probability estimates, Material A has a larger probability estimate for 'Strongly Preferred' to 'Extremely Preferred' category preference. On the other hand, Material C has higher probability estimates for category 'Not Preferred'. Based on these results, Material A (epoxy coating) is again the most preferred material followed by Material B (plastic). Material C (copper) as previously found is the least preferred plumbing material.

	Material A	Material B	Material C
Coefficient Estimates[a]			
Not Preferred	-1.919	-1.344	-0.147
Moderately Preferred	-0.472	0.103	1.300
Strongly Preferred	0.545	1.120	2.317
Very Strongly Preferred	2.018	2.593	3.790
Extremely Preferred			
Odds Ratio Estimates			
Not Preferred	0.147	0.261	0.863
Moderately Preferred	0.624	1.108	3.669
Strongly Preferred	1.724	3.064	10.145
Very Strongly Preferred	7.522	13.367	44.256
Extremely Preferred			
Distribution Estimates			
Not Preferred	0.128	0.207	0.463
Moderately Preferred	0.256	0.319	0.323
Strongly Preferred	0.249	0.228	0.124
Very Strongly Preferred	0.250	0.176	0.068
Extremely Preferred	0.117	0.070	0.022

aCoefficient estimates are built up from the statistically significant estimates for the attribute levels and threshold values. Coefficients are compared to the base "Extremely Preferred" level.

Table 13. Ordered logit regression results' analysis by plumbing material type (dependent variable represents the plumbing material valuation and the independent variables represent the plumbing material attributes and the socioeconomic characteristics).

As in the previous model specifications, Material A is the most preferred plumbing material when the CA data is estimated, employing an Ordered Logit Model with and without socioeconomic characteristics. Material C is the least preferred plumbing material. Two plumbing material attributes are important in making the decision on type of pipes to be installed in a house: 'plumbing material installation time' and 'corrosion risk'. The regression coefficients as well as the computed odds ratios and probability estimates differ between the model specification with and without the socioeconomic variables.

For example, for Material A, the odds ratios are lower for all preference categories in the case of model specification with socioeconomic variables, category 'Very Strongly Preferred' has odds ratios ranging from 9.034 to 14.083 for model without socioeconomic variables and 7.522 for model including socioeconomic variables. This finding implies that the socioeconomic variables impact the discrimination level between the plumbing material preference valuations. For example, if a household has experienced previous cost of plumbing repairs and/or replacement, their preference valuation level is lower for a more corrosion prone plumbing material compared to material with an attribute level of 'corrosion proof'.

The marginal distribution of probability estimates (Table 13) has higher values for lower preference categories for Material C in the case of model specification without socioeconomic variables. For example, for Material C, 'Not Preferred' has probability distribution estimate ranging between 0.476 compared to 0.463 (with socioeconomic variables). The marginal distribution estimates for higher preference valuation categories are lower for Material A and B for model without socioeconomic variables. For example, for Material A, 'Extremely Preferred' has a probability distribution estimate ranging from 0.074 (without socioeconomic) compared to 0.117 (with socioeconomic variables). As a result, the inclusion of socioeconomic variables raises the level of preference for Materials A and B, while it decreases the level of preference for Material C.

In conclusion, although the inclusion of socioeconomic variables does not change the final preference ranking of the plumbing materials, it increases the estimated level of preference for Material A (epoxy coating) and Material B (plastic) by increasing the marginal probability distribution of estimates for the higher preference categories (i.e. 'Strongly Preferred'). The increase is the most pronounced in the case of Material A (model with socioeconomic variables) for which the 'Extremely Preferred' category has a probability distribution estimate almost twice as large compared to the model specification without socioeconomic variables (0.117 vs. 0.074). The respondent's previous cost of plumbing material repairs and replacement impacts positively the preference level for plumbing materials described by 'corrosion proof' attribute level. This finding implies that Materials A and B are more highly preferred when socioeconomic factors are taken into consideration. Households experiencing high costs of fixing corrosion related damage in the past are more likely to prefer and choose materials with lower corrosion levels. The decreased corrosion level implies lower future plumbing material failures, and therefore, lower costs associated with repairs of water-related damage.

7. Conclusions and discussion

Due to the fact that homeowners have an important stake in finding plumbing systems appropriate for their households, they should not only rely on expert advice, but also acquire information on plumbing material attributes such as price, health impact, longevity, and corrosion resistance in order to make informed investment decisions about plumbing systems for their homes. Information on consumer preferences for drinking water plumbing attributes can be useful not only to individual households, but also to policymakers, program managers, water utilities, and firms with interests in drinking water infrastructure.

This chapter addressed the issues of household plumbing material decisions. The information was elicited by two surveys of residents residing in a Southeastern Community in the U.S. The first survey elicited information on the prevalence of pinhole leaks and other plumbing material failures, households' experiences with plumbing material failures, the cost of repairs and property damages due to the material failures, and household preferences for corrosion preventive measures. The follow-up survey, sent only to those residents who agreed to participate in future studies related to the plumbing material issues, elicited information on households' preferences for a set of hypothetical plumbing materials.

Overall, the Southeastern Community survey revealed high level of awareness of pinhole leak problem among residents of the community. Twenty percent of the households reported actual pinhole leak incidents. The percent of pinhole leak reports was on par with other hotspot areas of corrosion in the U.S., but above the rate of pinhole leak occurrences in non-hotspots (Scardina et al., 2007). The pinhole leak problem was more prevalent in houses built before the 1990s with copper pipes installed as the plumbing system. This finding is in an agreement with a Maryland Pinhole Leak Survey conducted by Kleczyk and Bosch in 2004.

The total repair expenses due to the pinhole leaks varied between $100 and $5,000 with several reports of more than $5,000 in repairs. Similar results were found by Kleczyk et al. (2006) of selected communities in the East, Southeast, Midwest, and West regions. Over 50% of surveyed respondents spent more than $100 on repairs with estimates as high as $12,000. In comparison, in their Maryland Pinhole Leak Survey, Kleczyk and Bosch (2008) found costs from the plumbing material failure repairs as high as $25,000. Unlike the present survey, however, the study by Kleczyk and Bosch (2008) did not separate the costs associated with pipe failure and property damage. This Southeastern Community survey accounted for this factor, which might have resulted in the differences between the two studies. Furthermore, many households in the Southeastern Community cited using a preventive measure against corrosion, including whole house re-plumbing and installation of water softeners. Over 80% of residents of the Southeastern Community were satisfied with the water quality in their homes.

The follow-up survey data of residents in the Southeastern Community revealed that among three hypothetical plumbing materials (A, B, and C), the households preferred Material A (epoxy coating) followed by Material B (plastic). Material C (copper) was the least preferred material in the set. This result was derived based on each of the respondents' preference evaluation of the different plumbing material groupings. The preference ranking of the materials was the same across both Ordered Logit model specifications (with and without socioeconomics variables). Furthermore, the results were in agreement with the survey baseline method, which ranked Material A as the most preferred and Material C as the least preferred. The baseline ranking of plumbing materials was obtained from households' comparisons of all three plumbing materials at the same time.

The plumbing material attributes that were important in the decision-making process included: 'corrosion risk' and 'time length of plumbing material installation.' In both cases, the attribute level rankings were in agreement with the transitivity assumption of preferences, and the lower corrosion risk attribute level, as well as shorter amount of time required for plumbing material installation was more preferred to the more corrosion risk prone and longer installation period attribute levels.

Only one socioeconomic variable had a statistically significant impact on the chosen plumbing material: 'cost of plumbing material repairs and replacement incurred by the respondent.' This variable was statistically influential when interacted with corrosion attribute levels. Although it did not change the preferences for plumbing materials, the variable skewed the preference valuations favorably towards plumbing materials described by 'corrosion proof' attribute level. This finding implies that the more each household had previously spent on repairs associated with plumbing material failures, the more they preferred a plumbing material with lower corrosion level to avoid future expenditures on drinking water system repairs.

There are several implications for further research that would improve the analysis of preferences for plumbing materials. The information set of plumbing material attributes might not have been the most complete and objective description of the pipe characteristics. Households with copper plumbing materials installed in their houses were more likely to identify Material C as copper (as noted on their questionnaires returned to the researchers), and therefore, might have evaluated it based on their experiences and not based on the comparison with other plumbing materials. This finding, however, is not unexpected, as part of the research question was to examine the impact of previous experiences with plumbing material failures on household decisions for corrosion prevention and plumbing material choices. Furthermore, in his AHP study, Lee (2008) noticed that some of the householders in this community provided a high degree of preference for a specific plumbing material in the survey, but in reality installed other types in their homes (Lee, 2008). As a result, in some cases, there is a mismatch between the stated preferences derived based on the homeowners' survey and the actual behavior exhibited by the households.

The above survey results inform policy makers, utility managers, and home plumbing systems producers on the homeowners' preferences for plumbing materials, and the trade-offs between the risk of corrosion and cost of a leak-free environment based on their experiences with pipe failures in the past. The cost of alternative preventive measures, corrosion risk, and convenience of plumbing material installation drive the decisions of homeowners regarding their plumbing system. As a result, policy makers should take into consideration the implications of new federal and state regulations on the interactions between drinking water and drinking water plumbing. Furthermore, their regulations and standards should accurately test the different types of plumbing materials used in the drinking water infrastructure, as well as their chemical and physical interactions with chemicals used to treat drinking water.

For example, Edwards et al. (2004) suggested that removal of natural organic matter mandated by tighter EPA drinking water standards contributed to the pinhole leak problem in combination with other factors, including faulty installation, since natural organic matter is an inhibitor to the corrosion-inducing chemical reactions. To deal with this problem, Bosch et al. (2006) found that almost 60% of water utilities added corrosion inhibitors, such as phosphate to water treatment. The inhibitors were added to protect water service lines, to comply with the lead and copper rule proposed by EPA, and to give protection to residential customers. Similarly, after adding phosphate to the water treatment process by utility companies who distribute water to the Southeastern Community, the Southeastern Community reported a decrease in the number of pinhole leak reports (Scardina & Edwards, 2007).

Furthermore, the cost associated with employment of different prevention options as well as the convenience of installation has an impact on households' decisions, concerning choosing a plumbing material for their houses. As a result, service providers (i.e. plumbers and material manufactures) should be sensitive to households' financial constraints and convenience of plumbing installation for homeowners. For example, 33% of Southern Community respondents with pinhole leaks spent at least $500 repairing damaged plumbing material, while more than 75% of survey participants with pinhole leaks experienced at least moderate level of stress. In their Maryland study of pinhole leak corrosion, Kleczyk and Bosch (2008) estimated the total cost[11] of fixing damage related to pinhole leaks to range from roughly $1,300 to more than $18,000. As a result, when plumbing services are expensive, the service providers should concentrate on installing plumbing materials that are convenient to install, and present a low failure rate to minimize future financial outlays spent on plumbing material repairs.

Finally, water professionals and policy makers should work on public policy that would address public preferences for drinking water infrastructure. Results of this Southeastern Community analysis can provide information to policy experts and water utility managers who are dealing with extensive corrosion problems in their areas. Information will fill the gaps of knowledge about corrosion occurrences, the financial impact of plumbing material repairs on households, and households' preferences for drinking water infrastructure, as well as the ability of householders to pay for different corrosion prevention options.

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[11] Total cost of repairing pinhole leak damage includes the financial and time costs.

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