Housing Characteristics Influencing Dust Levels found within the Home

By:

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Abstract
A previous study was performed measuring dust samples from 10 homes located in Tucson, Arizona. Mass floor loading of dust and dust fall measurements were taken for data analysis in original and current study. Mass floor loading of dust was measured by collecting floor particulate matter in a designated area within the home with a vacuum. Dust fall was measured by the amount of particulate matter in the air settling on filters placed within the home. Questionnaires and housing characteristics were assessed for further data inquires. The Wilcoxon Rank Sum test was used with the questionnaire for this subsequent study. The statistically conclusive parameters found to be influencing the amount of mass floor loading of dust were: HEPA filters within vacuums, air filters, and the landscape in the front yard. The parameters influencing dust fall were: the age of the carpets and the age of the home. For further analysis of house dust and different parameters affecting the home, a larger sample size should be taken.

Introduction

House dust is an accumulation of organic and inorganic particulate matter. It can come from a number of sources both indoor and outdoor. Dust can arise from ambient air moving outside particulate matter into the home. Organic matter, like pollen, and inorganic matter, such as heavy metals can be brought into the home from ambient air. Influences from inside the home can greatly affect the amount of overall dust found with the home. A study found the main contributors to dust within the home are the presence of carpets, animals, and the overall cleaning habits of the inhabitants (Gehring et al., 2001). Some quantitative measures, such as calculating the square footage of a dust sample collected, can be used to analyze the amount of dust fall within the home compared to different housing characteristics, such as the building shell and the amount of individual activity within the home. Individual activities are speculated to contribute to fluctuating amounts of resuspension of dust within the home. Overall human activity within the home has been shown to correlate with higher amounts of particulate matter and dust fall (Chen et al, 2008).

Purpose and Relevance

This study was designed to further understand the properties of the home and surrounding environmental influences that contribute to the amount of dust within homes. The future goals for this study are to find significant environmental influences or hygiene habits that directly contribute to the amount of dust found within the home. The long term goal is to be able to identify the causes of higher amounts of dust within the homes and to eventually come up with practical solutions to lowering those levels. This goal is specifically geared to potentially lowering exposures from possible contaminants found in dust, such as heavy metals or pesticides. Eventually, improvements will hopefully be made to reduce the amount of health problems caused by dust contaminants within the home. My goal is to understand parameters of the home and their relationships with mass floor loading (Mfl) and dust fall rate (Df). Mass floor loading was found by collecting the dust accumulated on the floors of the residence, based on where the individuals supposedly spend the majority of their time. Dust fall was collected by setting up sites around the home where dust and particulate matter from the air was able to settle in cylinders at a designated height for a period of time.

Methods

A previous study, lead by Dr. Paloma Beamer, measured dust levels using Mfl, Df, and metal concentrations found within the soil leading to the accumulation of dust found within the home. The previous study's data was the sole source of data information used for the experiment. The study consisted of questionnaires about the individuals cleaning habits, the housing characteristics, and the landscape surrounding the home.

Methods for collecting and measuring dust fall

Dust fall collection consisted of four gallon metal catchment cylinders with lids, a rolling cart on which the cylinders were able to rest upon, and 120 mm borosilicate filters. The rolling cart was 2.95 feet high and 1.65 feet wide. Clean catchment cylinders and their lids were properly sterilized using isopropyl alcohol and kim wipes The borosilicate filters, which were trimmed to 120mm in diameter, were fit into the bottom of the collection cylinder. Gloves were used to place the filters in and out of the bottom of the four cans. An ultra-micro analytical balance, which is capable of measuring 0.1 micrograms, was used in the laboratory.

The original study calculated dust fall in relation to the amount of days the cylinders were allowed to sit and collect dust from the air. The overall units for the calculation was grams of dust collected on the filter divided by the area of the filter (meters squared) for every day the sample was left to collect dust, which was 7 days. The original equation used was:

$$Df = \frac{M}{A \times D}$$

where Df is the rate of dust fall to floors collected (g m^{-2} d^{-1}) ; A is the area that was measured for the dust sample taken (m^2); and D is the number of days the sample was allowed to stay out to collect dust (d^{-1}).

However, if there were multiple samples collected from a residence, the average of the areas was then calculated. The amount of dust fall collected from the cylinders was measured and multiplied by the individual areas of the cylinders collected from and then divided by the overall area that was sampled.

$$Df = \frac{(Df_1 \times A_1) + (Df_2 \times A_2)}{(A_1 + A_2)}$$

Df is the averaged rate of dust fall on floors that was collected from previous data; Df_1 is the rate of dust fall on floors collected for the first sample (g m^{-2} d^{-1}); Df_2 is the rate of dust fall on floors collected for the second sample (g m^{-2} d^{-1}); A_1 is the area of the floor where the first sample was taken (m^2); and A_2 is the area of the floor where the second sample was taken (m^2).

Materials and Methods for Measuring Mass Floor Loading of Dust

Floor dust samples were taken from the room where residents were proposed to spend more of their time within the home. This is usually the room where the television is located. The samples were collected primarily from a 2.2 horse power Hoover commercial vacuum cleaner with a six inch wand and a specialized vacuum inlet. The vacuum inlet consisted of a head and a tail and was made of stainless steel. The vacuum had a plexiglass device that was used to aid in trapping the dust on the filter. A field kit was used, which contained: a filter holder made of a stainless steel screen, a filter insertion ring made of plastic, filter packets with a pre-weighted filter, field sheet, custody records, and extra Ziploc baggies. Other materials that were used included a four meter long chain and a labeling pen.

A site was selected based on the type of flooring; it was assumed that carpeted areas were going to hold more dust than tile, brick, or wood surfaces. Areas near the television or couch were good candidates for sampling because it has been found more individuals spend their time around the television. The four meter chain was used for measuring out exactly one meter squared. Sample collections were chosen based on proportions of the floor surface. For example, if the carpet was only 20% of the home, only 20% of the sample collected should be from the carpet. Every time a sample was taken, the vacuum cleaner was emptied before operation. The vacuum inlet and the stainless steel tray were also thoroughly cleaned and allowed to air dry to ensure only the dust collected was from the site of collection. There was continuous vacuuming of the site selected until at least two grams of a sample was collected. The original calculations to measure the mass floor loading of dust while working in the field is shown below. The units for the original collection was the mass in grams per meter squared, or (g/m^2).

$$Mfl = \frac{M}{A}$$

Where Mfl is the mass floor loading of dust collected on the floor surface of a residence (g d^{-1}); M is the mass of the sample collected (g); and A is the floor area of the residence where the sample was collected (m^2).

Some homes had multiple samples that were collected. For homes with multiple samples of dust, the individual sample sizes collected for given areas were calculated and were then divided by the overall areas used for sampling. The units for Mfl were grams/ meter squared, (g m^{-2}).

$$Mfl = \frac{(Mfl_1 \times A_1) + (Mfl_2 \times A_2)}{(A_1 + A_2)}$$

Where Mfl is the average of mass floor loading of dust collected on the floor surfaces within the home (g m^{-2}); Mfl_1 is the first sample collected from the mass floor loading of dust on the floor surface; Mfl_2 is the second sample collected from the mass floor loading of dust on the floor surface; A_1 is the area of the first sample that was collected in the residence (m^2) ; and A_2 was the floor area of the second sample that was collected in the residence (m^2).

Data Analysis

The responses to the survey were compared to the dust fall and mass floor loading of dust using tree models. Tree analysis was used to identify natural groupings in the data, for each questionnaire response with respect to Mfl and Df. The tree models showed which category had higher amounts of dust overall within the home. The categories were then compared to the amount of dust fall and mass floor loading through box plots. The goal of the box plots are to indicate which category for the housing characteristics has a larger amount of dust fall or mass floor loading of dust.

The two-sample Wilcoxon rank sum test was used to determine if there were significant differences between the groups for each survey response with respect to levels of Df or Mfl. Due to the small sample size (n=10), the groups were determined to be significantly different if the p-value was less than 0 .15.

Results

A total of 10 homes were sampled for dust fall and mass floor loading of dust. The characteristics of each home, the significant p-values, and finally the categories used for each characteristic in the home are presented in Table 1. There were a few significant findings relating to mass floor loading, the first included how often the air filter got changed within the home. The results indicated there was more dust found within the home when the air filter was changed less frequently than every three months (Figure 1). The second significant finding for Mfl was the presence or absence of HEPA (high efficiency particulate air) filters in vacuum cleaners. The results indicated there was more mass floor loading of dust with vacuums that had a HEPA filter (Figure 2). Finally, the last significant finding for Mfl was the percentage of bare dirt in the front yard. There was a higher amount of dust found when there was more than just bare dirt within the front yard (Figure 3). Dust fall within the home was also found to have statistically significant categories. One significant finding was the carpets age within the home and the amount of Df being higher in homes with carpets that were younger than 10 years old (Figure 4). Finally, the last significant value for Df was the age of the dwelling, which indicated there was more Df found with homes that were older (Figure 5).

Table 1: Characteristics of the home with their individual categories and p-values

Characteristics	Categories	Category with more Dust Fall	Category with more Mass Floor Loading	Dust Fall p-values	Mass Floor loading p-values
Laundering Facilities	1. Inside (n=8) 2. Outside (n=2)	1	2	0.533	0.6944
Percentage of bare dirt in back yard	1. Bare dirt (n=0) 2. No bare dirt (n-10)	2	2	0.9143	0
Percentage of bare dirt in front yard	1. Bare dirt (n=2) 2. No bare dirt (n=7)	2	2	0.1833	0.1373
Mats inside and outside the home.	1. Mats inside and outside (n=3) 2. No mats in the inside and outside (n=7)	1	2	0.1833	0.5676
Types of flooring	1. Carpet/area rug/ tile carpet (n=8) 2. Tile, wood, non-carpet(n=2)	1	1	1	0.3593
When home was cleaned last	1. 1 -2 days ago (n=6) 2. 1 week ago or longer (n=4)	1	2	0.9143	1
Number of dogs occupying the home.	1. 1 Dog or less (n=5) 2. 2 dogs or greater (n=5)	2	1	0.1508	0.2948
Total number of pets within the home.	1. No pets (n=3) 2. Pets (n=7)	1	1	1	0.8192
Window Panes	1. Single (n=4) 2. Double (n=4)	equal	1	1	0.8857
Frequency the vacuum bag was changed.	1. Changed every 2 weeks or less (n=2) 2. Changed greater than 2 weeks in between (n=3)	2	1	0.8	0.2
Peeling of paint on inside of home.	1. No peeling (n=3) 2. Peeling (n=1)	1	1	0.5	0.6347
How often air filter gets	1. Changed every 3 months or less	1	2	0.6286	0.009

changed.	(n=4) 2. Changed greater than 3 months (n=3)				
Carpets age in home.	1. Less than 10 years (n=3) 2. Greater than 10 years (n=5)	1	2	0.1429	0.5714
Number of cats in the home.	1. No cats (n=7) 2. Cats (n=3)	2	1	0.5167	0.8192
Total number of people occupying the home.	1. 1 person (n=1) 2. More than 1 person (n=9)	2	2	0.4	0.1625
House away on the weekend.	1. 0-4 hours away (n=4) 2. 5+ hours away (n=6)	1	1	0.4762	0.5212
Hours away on the weekday.	1. 0-4 hours away (n=2) 2. 5+ hours away (n=8)	2	2	0.1778	0.6944
Number of children in the home.	1. No children (n=5) 2. Some Children (n=5)	1	equal	1	1
Frequency the doors/windows are left open.	1. 1-2 times a month or less (n=3) 2. 1 time /week or greater (n=7)	1	1	0.5167	0.909
Method of cooling within the home.	1. Air Conditioning (n=6) 2. Evaporative/all other (n=4)	1	2	0.9143	0.5929
How long resident lived in the home.	1. Less than 10 years (n=5) 2. Ten years or greater (n-5)	1	2	0.1508	0.2087
How old the dwelling is.	1. Less than 10 years (n=3) 2. Ten years or greater (n=7)	1	2	0.0667	0.253
Rent or own.	1. Rent (n=9) 2. Own (n=1)	1	1	0.8	0.7269
Vacuum with or without a HEPA filter	1. No HEPA filter (n=6) 2. HEPA filter (n=3)	2	2	1	0.0069

Figure 1. How often the Air filter gets changed in homes vs. the Mfl category. The first category shows homes (n=4) that had their air filters changed their air filters every three months or less. The second category shows homes (n=3) that were changed greater than three months. The second category had a higher amount of MFL with a p-value of 0.009.

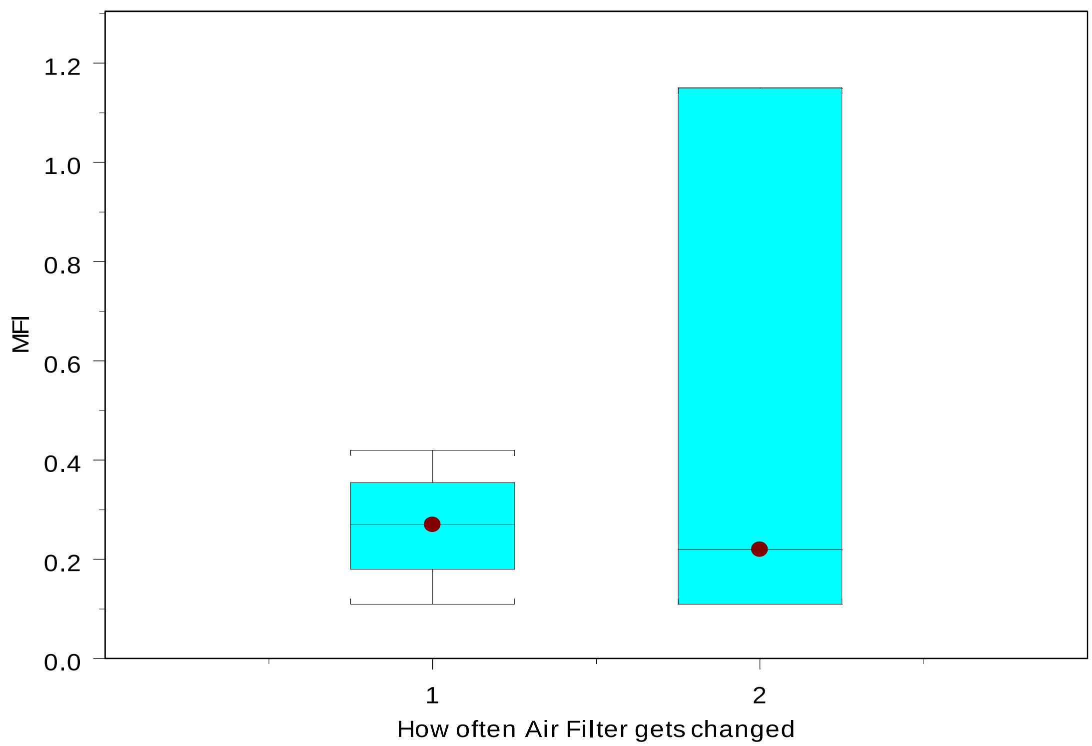


Figure 2: Vacuum bags with or without a HEPA filter in homes vs. MFL category. The first category includes homes (n=2) that have vacuums with no HEPA filter. The second category (n=3) includes homes that have vacuums with a HEPA filter. The second category was shown to have a higher distribution of homes with a higher Mfl. The first column appeared to have a lower mean value for homes without a HEPA filter. The p-value was significant with a a value of 0.0069.

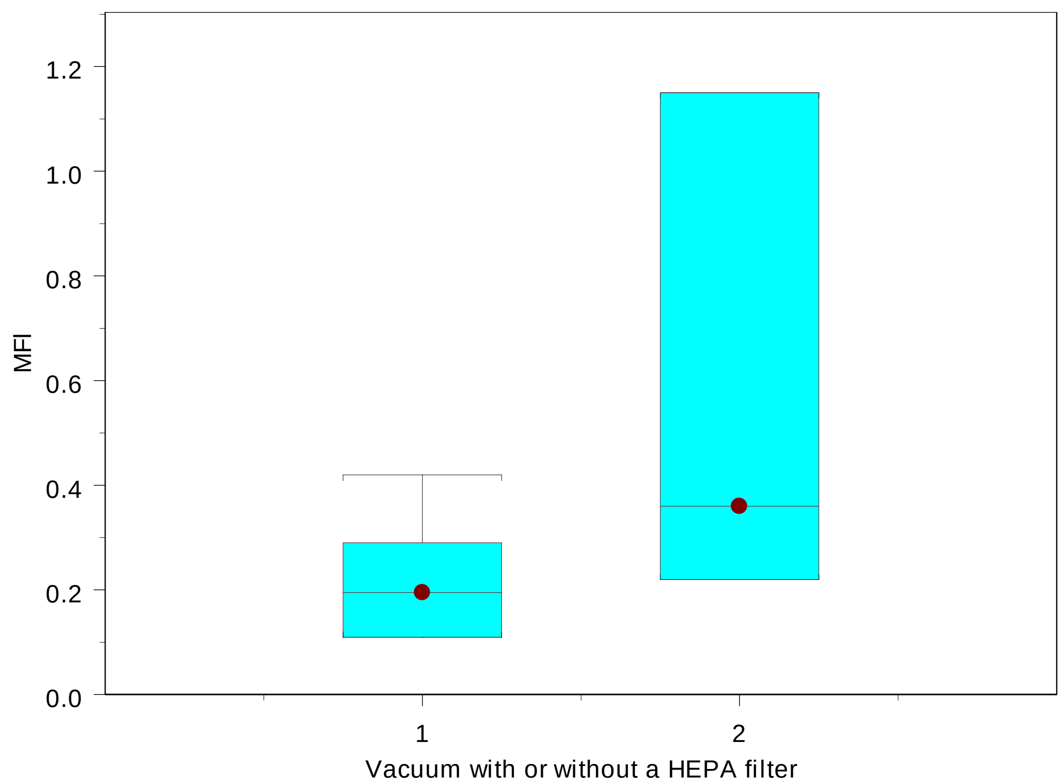


Figure 3. Percentage of homes with bare dirt in the front yard vs. Mfl category.

The first category shows homes (n=2) with bare dirt only. The second category shows homes (n=7) with yards that have no bare dirt. The second category had greater overall Mfl with a p-value of 0.1373, indicating it was significant.

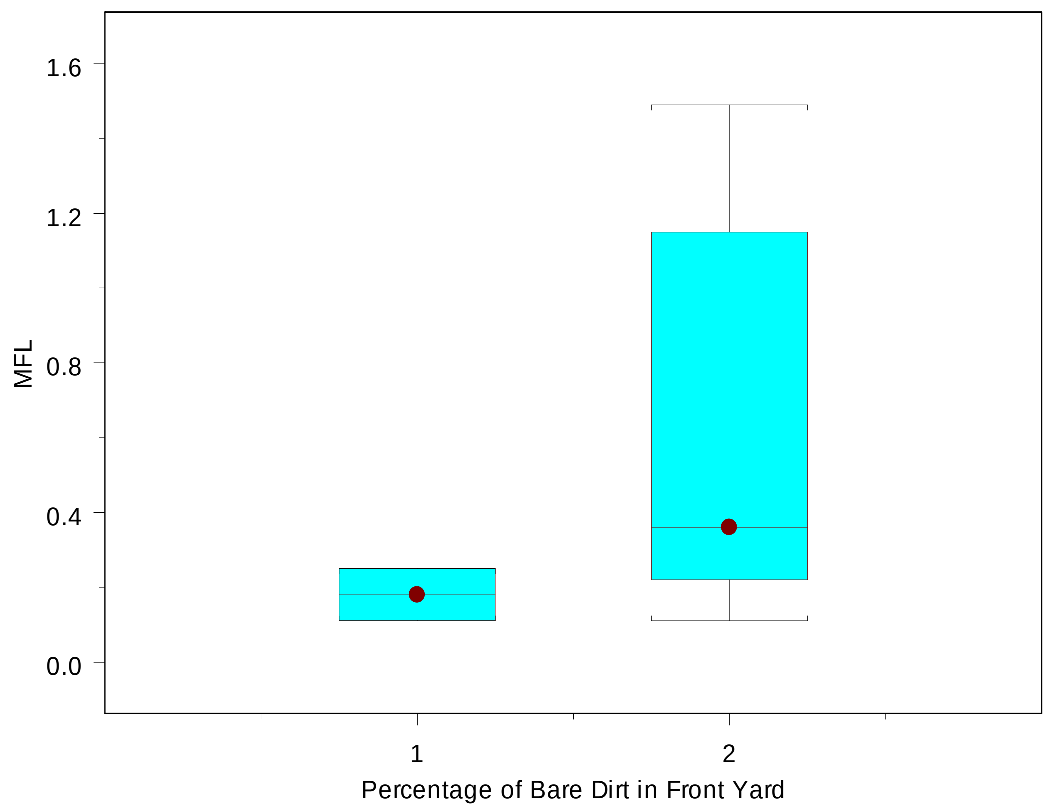


Figure 4: The carpets age within the home vs. DF category. The first category showed homes (n=3) that have carpets less than 10 years old. The second category showed homes (n=5) that had carpets older than 10 years. The second category indicated there were more homes with greater DF, with a p-value of 0.1429.

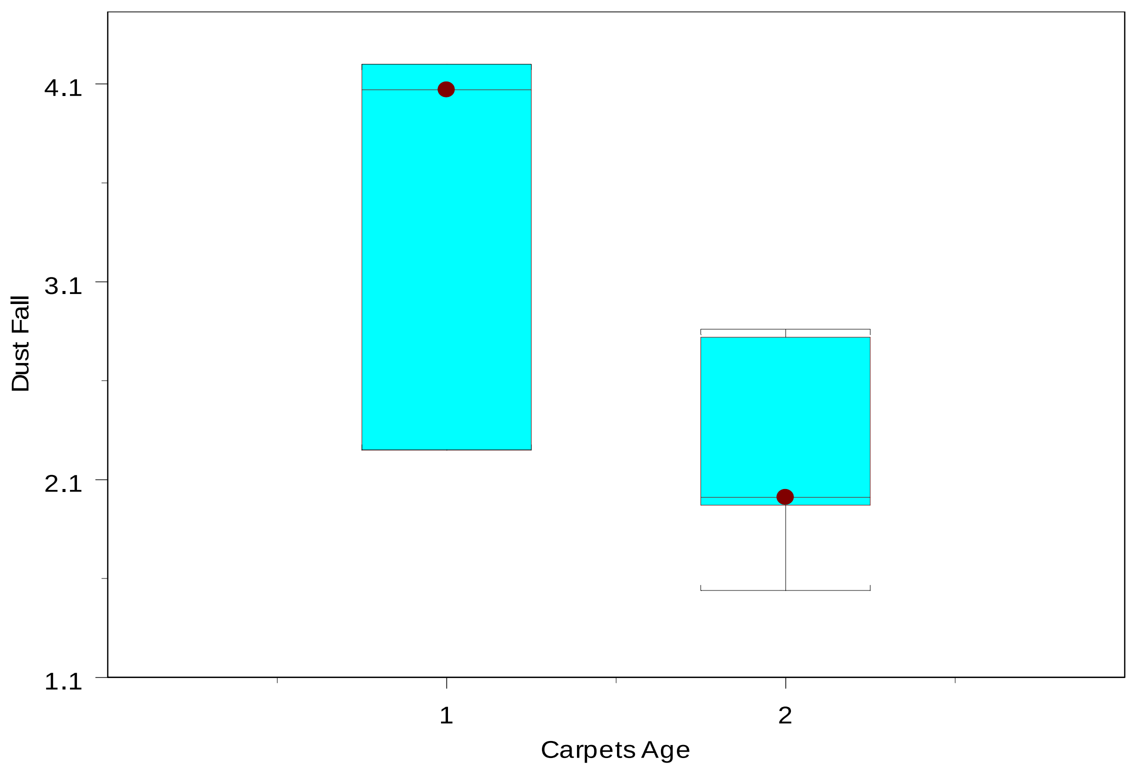
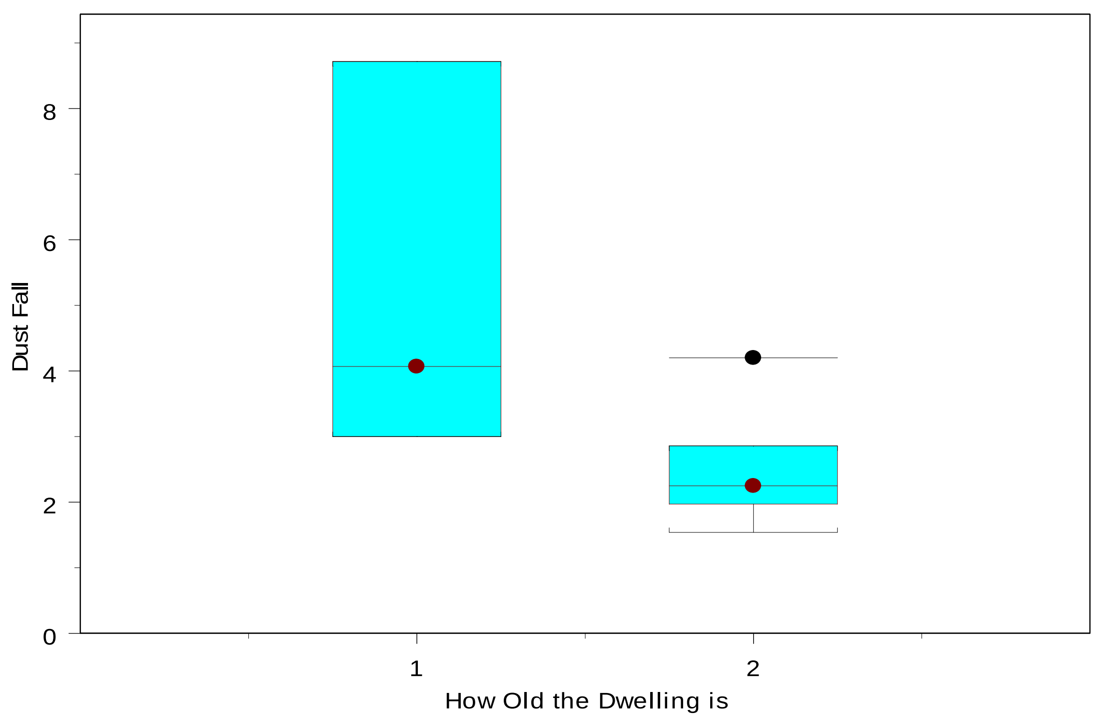


Figure 5: How old the dwelling was vs. DF category. The first category includes homes (n=3) that are younger than 10 years old. The second category includes homes (n=7) that are older than 10 years. The first category indicates there is greater DF, with a p-value of 0.0667.



Discussion

Housing characteristics may influence the amount of penetration of outdoor contaminants and dust that enter the home through ambient air. Mass floor loading of dust and dust fall were the main parameters evaluated for fluctuations of dust found within the home due to a variety of characteristics. The characteristics evaluated included housing shell characteristics and individual hygiene of the home.

There was a limited number of homes that were selected (n=10), therefore there were many categories that simply did not have enough data to assess significance. During the study, statistically significant values were identified and certain housing characteristics were shown to influence the amount of Mfl and Df found within the home. The significant findings found in the study compared to mass floor loading of dust included: the frequency the air filter was changed, vacuum bags with or without HEPA filters, and percentage of bare dirt within the front yard. The statistically significant categories found relating to dust fall included: the age of the carpet and how old the home was.

The air filters changed less frequently were shown to have more mass floor loading of dust. Suggestive evidence indicates air filters that accumulate dust particles start to see a “filter cake” effect. This effect shows particulate matter previously collected becoming a filter for more dust particles. Therefore, more particulate matter accumulates around the home because there is not enough room to keep the dust particles attached to filter. This “filter cake” effect is heightened because larger particles may likely settle while smaller particles may stay suspeneded in air longer and have more opportunities to be captured on HVAC (heating, ventilating, and air conditioning) filters (Noris et al., 2010).

The second significant finding, indicated homes that had a HEPA filter in their vacuum had higher amounts of MFl. A possible suggestion could include making the HEPA filter work harder to suck the debris up into the vacuum because it provides extra air resistance. The overall vacuum cleaner has an overall drop in pressure and therefore it would not pick up as much dust as a vacuum without a HEPA filter. Overall, this would leave more particulate matter that could be potentially harmful to an individual's health within the home. The concentration of airborne irritants and allergens is affected by both the rate of production and removal (Reisman et al., 1990).

The last statistically significant category relating to mass floor loading was homes that had landscapes with or without bare dirt in their front yards. Suggestive evidence indicates landscapes that did have shrubberies, trees, grass, or concrete had smaller, fine particles that were easily resuspended in the air. This is compared to coarser, compact dirt that is found in the all bare dirt landscapes. This is speculated to be possibly biased because of the small sample size and the number of individuals having bare dirt in their yards had only two people (n=2). Wind blowing has been found to be one of the main contributors of dust spread to different areas throughout the world. The dust composition was found to have a mixture of mineral and organic particles, the latter consisting of tiny fragments derived from plants common in the central part of the continent (Simonson, 1994).

The current study indicated homes with carpets that were older than 10 years old were found to have a larger rate of dust fall. Furthermore, the age of the home was also found to be statistically significant in the study. Chen and associates (2009) found homes with wall-to-wall carpets or built before 1970 tended to have elevated geometric means of particulate and microbial levels. Suggestions for explaining the higher amounts of dust fall in homes that were older could be that older homes have more ambient air passing into the home because they are not as tightly sealed. Experimentally, the penetration factor has been determined either by raising the infiltration rate by depressurization, (Roed and Cannell, 1987) raising the outdoor particle concentration (Cristy and Chester, 1981), or by measuring the indoor deposition rate (Thatcher, 1994). Buildings are normally thought to reduce inhalation exposures to ambient, airborne contaminants because of the filtering effect of the building shell (Engelmann, 1992; Alzona et al., 1979). Suggestions for explaining why dust fall would have an effect on carpets could be because more particles get ground into the carpet from years of use. Kildeso and coworkers (1999) also reported that coarser particles are more easily resuspended from carpeting than fine particles and Ferro et al.(2004) found one home that typical human activities more readily resuspend particle from carpeting than from smooth floors.

Other research conducted indicated the number of dogs within the home and how long the individual lived within the home are direct contributors to the amount of overall dust found within the home. Indoor pets were associated with elevated airborne particulate matter and bioaerosols inside homes (Chen and Hildemann, 2009). The current study did not find this to be significant; this could possibly be due to a smaller sample size and the manner in which the questionnaires were answered. Other studies found significance in human activity and in the amount of dust resuspension found within the home. The current study did not find this particular category to be statistically significant, which could again be due to the extremely small number of homes tested (n=10).Clayton and associates (1993) showed the indoor particle concentration is higher during active hours that during inactive hours, although some of this increase may also be due to generation from cooking, household product use, or other indoor sources. Furthermore, with more people living in the home and contributing to the amount of dust found, there could be higher amounts of dust due to activity within the home. This was further proven by Chen and associates (2009), indicating the varying amounts of particulate matter found during sampling of a site could possibly be due to: home-to-home variability in human activities, in ventilation and/or particle penetration efficiencies, or in other house characteristics.

Dr. Beamer and coworkers took samples from ten homes and localized the samples to the most used room in the house, which was determined to be the living room. However, evidence suggests when the windows and doors are closed for a long period and there are minor indoor activities that did not produce significant amounts of aerosol particles, and the particle number concentration showed similar levels in different indoor locations (Hussein et al., 2006). The flow of ambient air contributing to the amount and whereabouts of dust fall and mass loading of dust can greatly depend upon the housing characteristics, the amount of outside influence and the amount of human activities within the home. Overall, there very many complicated variables needed to be considered for fully understanding what factors directly contribute to higher amounts of dust within the home.

Conclusion

Statistical evidence based on the Wilcoxon rank sum test and the box plots showed significant differences for dust fall and mass floor loading of dust based on some individual criteria of the home and the personal hygiene to the home. The significant values found for mass floor loading were: the amount of bare dirt surrounding the front yard, how often the air filter gets changed, and finally if the vacuum had a HEPA filter. The significant factors affecting dust fall were the age of the carpet within the home and the age of the home. Higher amounts of dust fall and mass floor loading can be a based on a variety of factors. It is speculated individuals habits within the home and their cleaning patterns could possibly influence the amount of dust found. Further research is needed to understand what factors influence dust and particulate matter in homes.

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