

# High-Resolution Analysis of the Spatial Distribution of Nicotine for Improved Methods of Thirdhand Smoke Exposure Assessment



San Diego State University

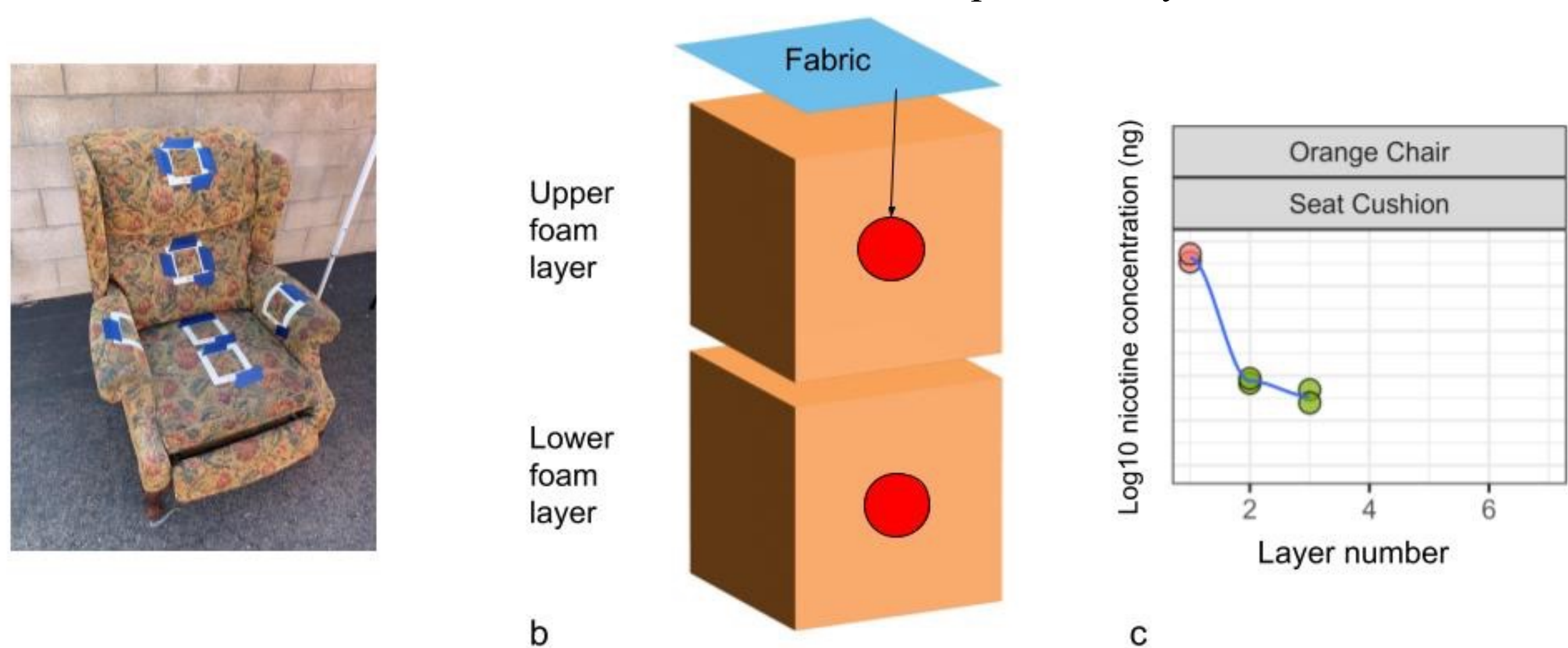
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## Background

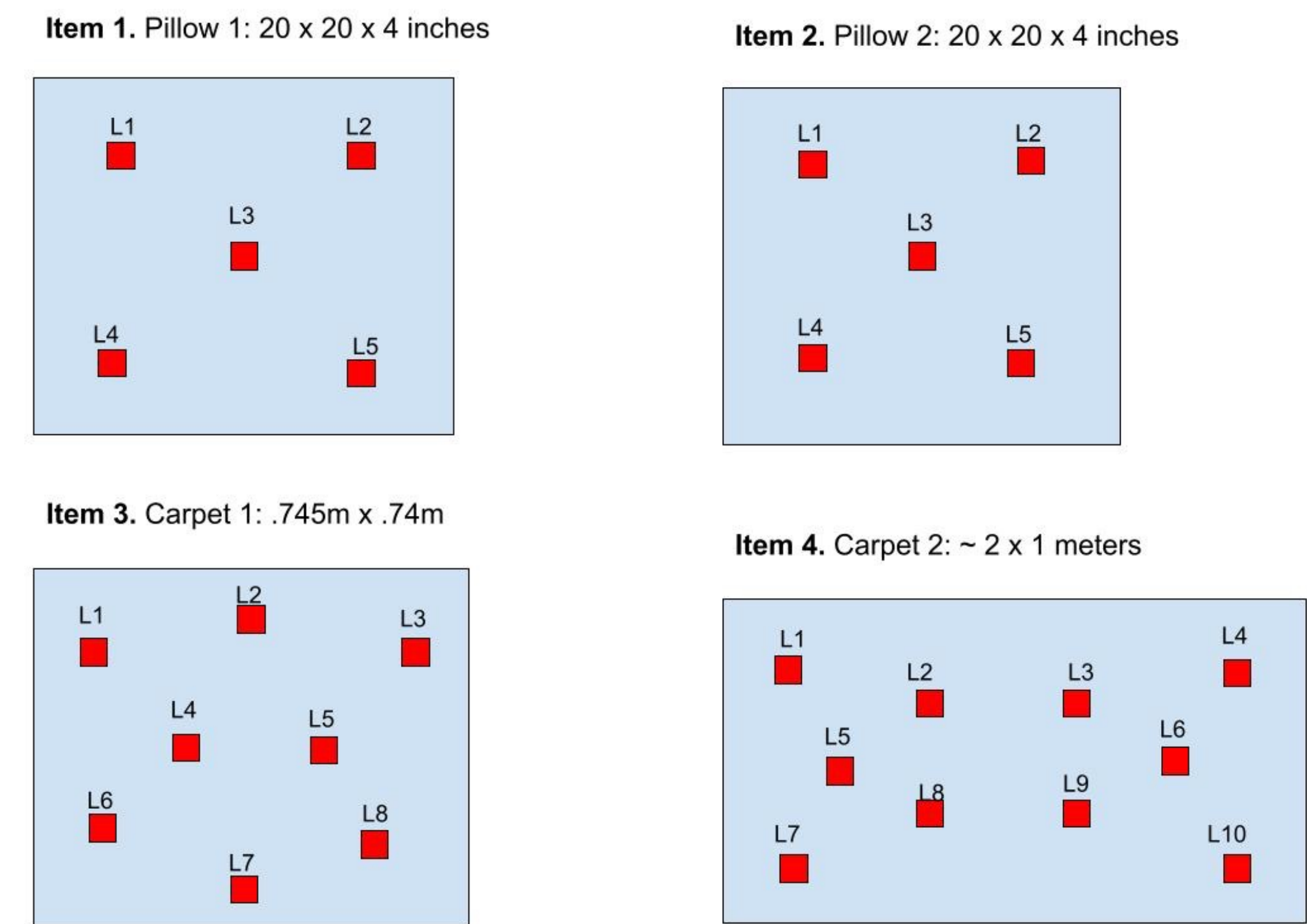
- Thirdhand smoke (THS) pollution is pervasive in the household furniture of smokers and poses health risks due to its ability to persist in furniture for extended periods.
- The current sample collection method from materials, such as carpet, upholstery, and drywall, involves cutting a single sample from a section of the item for nicotine analysis (Figure 1a). This method of sample collection may not be representative of the nicotine concentration of the entire surface of the section or the whole core of the foam for the upholstery samples.
- From the core samples taken in the previous study, three layers were analyzed for nicotine: the top fabric layer, the upper foam layer, and the lower foam layer. Analytical samples were taken from the center of each layer (Figure 1b).
- While a predicted line is drawn from layer one to layer two (Figure 1c), its accuracy is uncertain. Higher-resolution vertical analysis is needed to explain this decrease and to better understand the distribution of nicotine concentration between the top fabric layer and the center of the upper



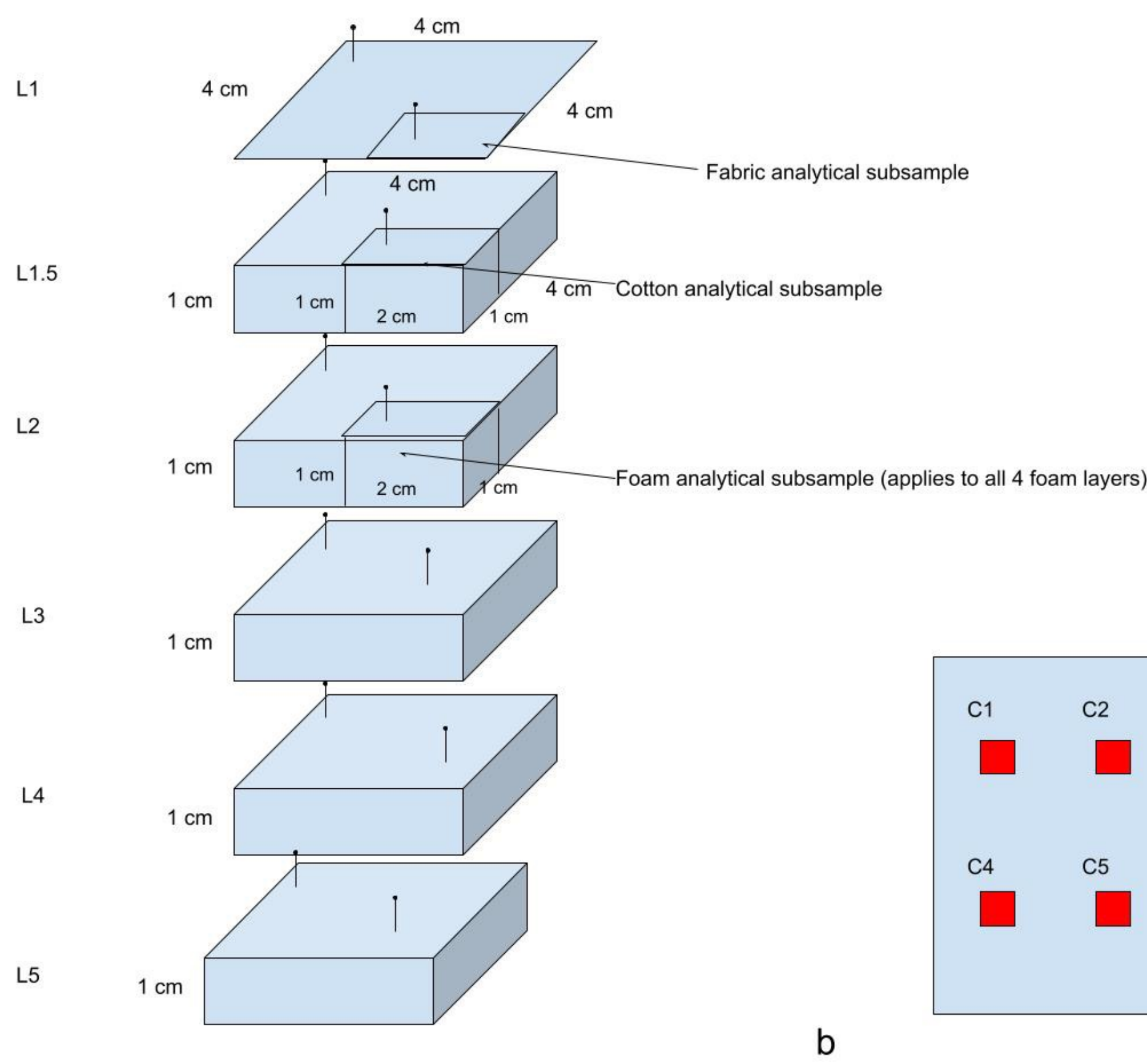
**Figure 1:** a) The previous sampling method used to analyze thirdhand smoke in furniture. Locations representing the backrest, seat cushion, and armrests. b) Three core layers were examined for nicotine: the top fabric layer, the upper foam layer, and the lower foam layer. Analytical samples were collected from the center of each layer. c) A panel from the results graph of the previous experiment shows a significant decrease in nicotine concentration from the first layer to the second layer.

## Methods

- This study investigated nicotine distribution across surfaces and vertically within furniture. The surface area analysis included two pillows (5 samples each) and two carpets (8 and 10 samples, respectively). For vertical profiling, samples were collected from a surface fabric layer (L1), an intermediate fiber layer (L1.5), and four foam layers (L2-L5).
- Nicotine concentrations were quantified using mass spectrometry, with data visualization in Python and statistical analysis in R supported by Gemini AI. Moran's I was identified as a statistical method to assess spatial variability. A permutation test was performed due to the small sample size. To complete this analysis, Google Colab was utilized with the R programming language.



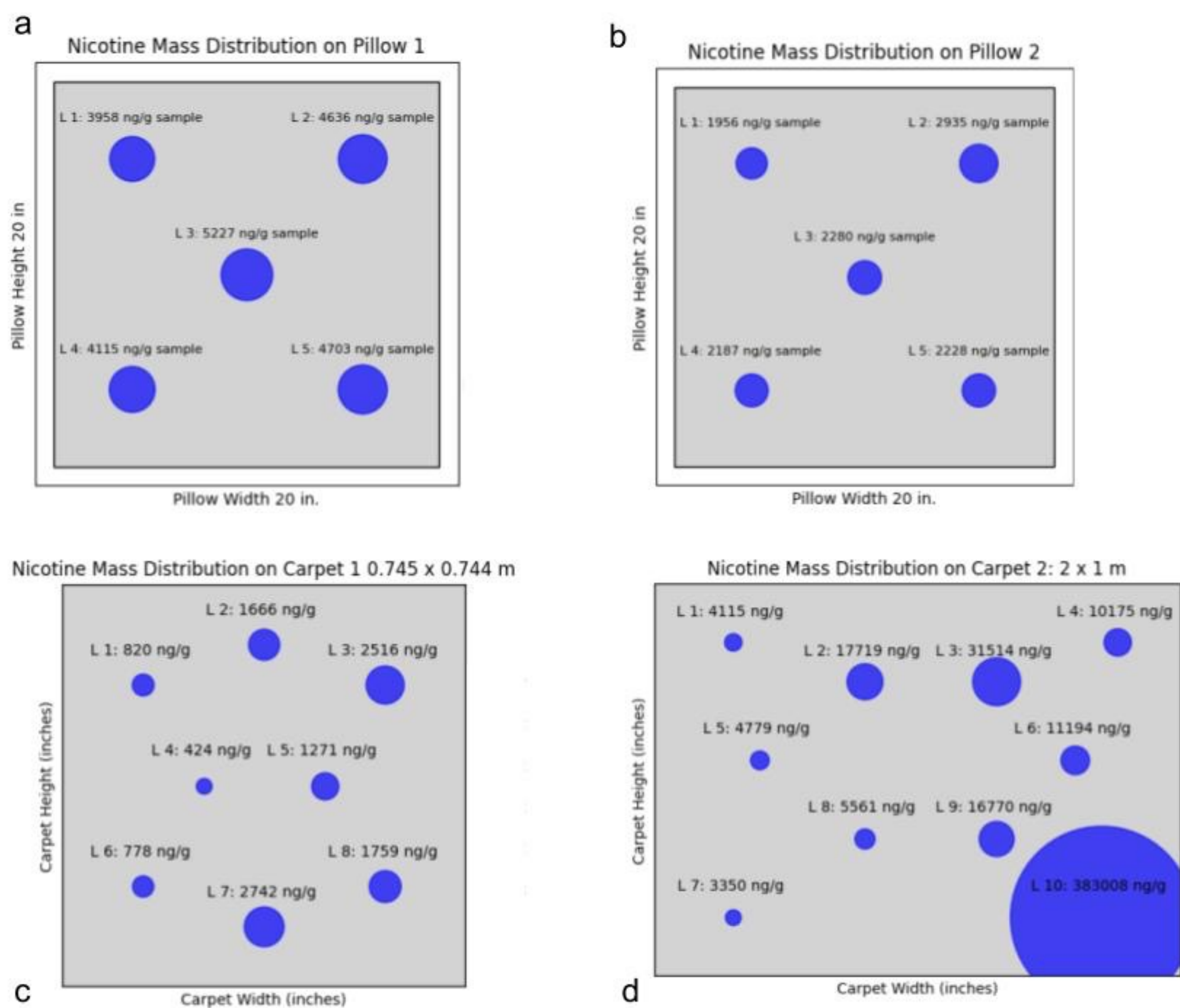
**Figure 2:** A schematic representation of the sampling process, illustrating the locations of each fabric sample collected from each item, and the size of each item.



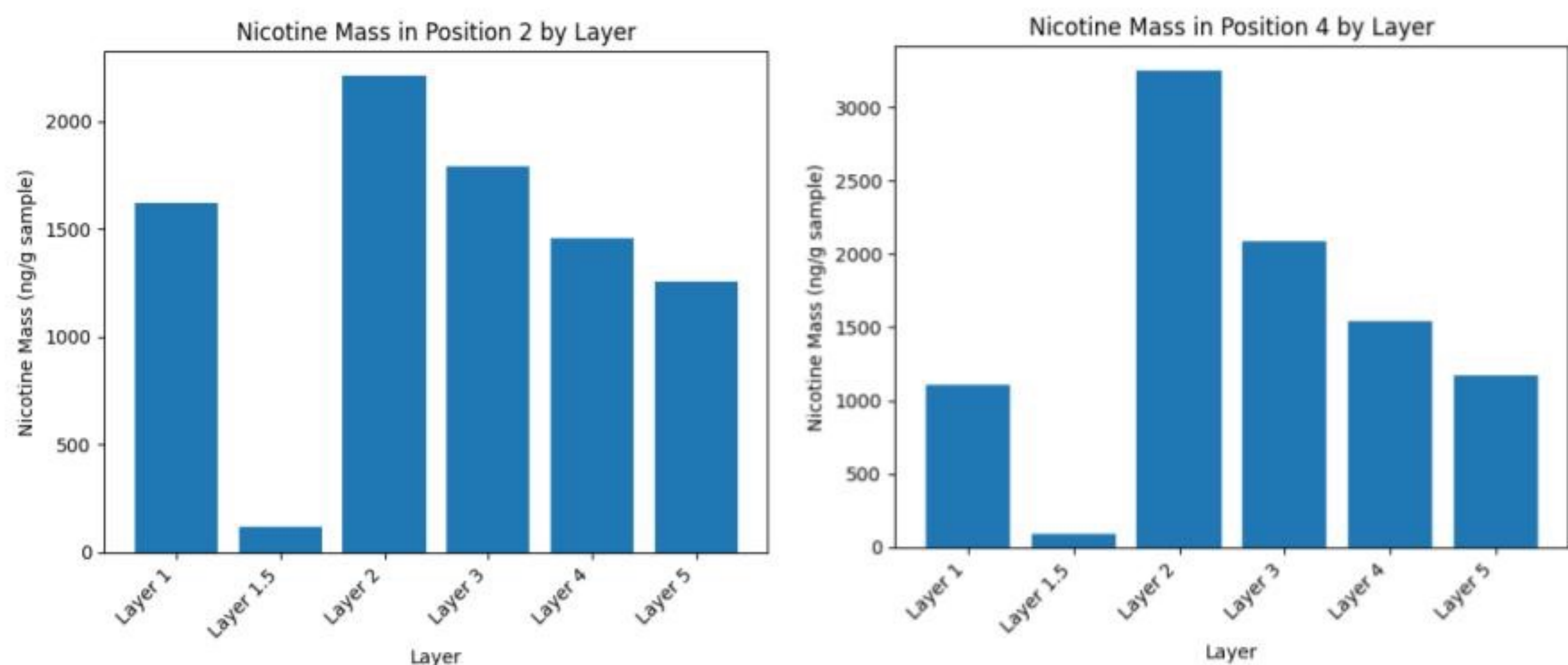
**Figure 3:** a) How each layer is cut from each of the six cores on the item from the top fabric sample (L1), the second cotton sample (L1.5), each foam sample, and the final analytical sample (L2 - L5). b) Top view of the item showing six cores taken from six evenly spaced locations, each core measuring 4x4 cm.

## Results

- Results indicated no significant spatial autocorrelation for nicotine on pillows (Moran's I: -0.25, p=1), whereas carpets showed significant negative spatial autocorrelation (Moran's I: -0.25, p=0.001). Pillow samples demonstrated low variability in nicotine concentration across their surfaces.
- The vertical analysis found higher nicotine concentrations in the upper foam layers (L2-3) compared to the surface fabric (L1). The fiber layer (L1.5) exhibited significantly lower nicotine levels than other layers.



**Figure 4 (a-d):** Diagrams representing nicotine concentrations (ng/g) per sample at each sampling location across the surface area of individual items. Dot size corresponds to the measured nicotine level.



**Figure 5:** Nicotine concentrations (ng/g) per sample in each vertical layer (L1–L5) of Position 2 and Position 4. Layers include: L1 (top fabric), L1.5 (top fiber), and L2–L5 (foam layers).

	Pillow 1	Pillow 2	Carpet 1	Carpet 2
Observed Moran's I	-0.25	-0.25	-0.25	-0.25
Permutation Test p-value	1	1	0.001	0.001

**Table 1:** Results of Moran's I with permutation test. The observed Moran's I and the p-value from the permutation test for each item. Moran's I test was done to assess spatial autocorrelation between the nicotine concentration (ng/g per sample) at each measured location on the furniture item.

## Discussion

### Surface Area Analysis

- The uniform pillow results could be attributed to the material, the usage pattern, or consistent tobacco contamination sources across the surface area.
- The significant variability within two carpets may be attributed to localized contact or foot traffic. Additionally, the differences in how carpet fibers trap and retain THS residues compared to the pillow fabric. Variations between carpet one and carpet two could be caused by the different types of carpet fibers.
- Locations 1, 5, and 7 on carpet two display lower nicotine concentrations compared to the other areas. This variation could be due to the presence of a dresser or large furniture piece that might have obstructed these locations, as indicated by the differences in coloration observed while collecting the samples.

### Vertical Analysis

- The analysis of nicotine distribution shows notable consistency between cores 2 and 4 (Figure 5), demonstrating that analyzing two out of the six total vertical cores for nicotine is sufficient and representative of the entire item.
- The results of this experiment suggest that foam materials have a greater capacity to absorb THS compared to fabrics and fibers.

## Acknowledgements

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