

**DESIGN AND STRUCTURE OF MULTI-CITY STUDY**

**submitted to**

**3M Environmental Laboratory  
935 Bush Avenue  
St. Paul, MN 55144**

**submitted by**

**Marcia Nishioka, MS and Warren Strauss, MS**

**Atmospheric Sciences and Applied Technology Department  
Statistics and Data Analysis Department**

**BATTELLE MEMORIAL INSTITUTE  
505 King Avenue  
Columbus, OH 43201**

**May 1, 2000**

## **Purpose**

The Multi-City study was designed to obtain preliminary data about dispersion of fluorochemical compounds in the environment, uptake into foods and presence in drinking water, and to understand the potential sources of human exposures that might result from this type of dispersion.

## **Methodology**

The types of samples that would be needed to establish baseline environmental levels, test hypotheses about secondary point sources (e.g., landfills and POTW plants) and dispersion via air and water, and determine whether human exposures result from environmental dispersion are listed in Table 1. These samples encompass various types of water and food samples, various types of samples from secondary sources, and samples from the environmental reservoirs of sediments and air.

These samples are being collected from diverse cities/towns (cities) of the US according to a statistical design and selection process. A case/control study design was selected for this investigation because this design is generally efficient with respect to power and sample size in identifying trends and drawing conclusions. For the purposes of this study, the test case group consists of those cities that are known to have a major producer or user of 3M fluorochemical compounds since 1993. The test control group consists of cities that do not have a major producer or user of 3M fluorochemical compounds (since 1993), *and* exhibit similar characteristics as the case study cities with respect to population size and drinking water source type.

The case/control design was also selected because of its ability to test hypotheses about the role of primary and secondary sources with respect to the levels of fluorochemical compounds measured in the environmental and food media. Primary sources are those manufacturing operations associated with production and/or use of 3M fluorochemical compounds. Primary sources do not exist in all cities of the US. Secondary sources exist in all cities of the US. Secondary sources are the POTW and landfill operations that receive fluorochemical compound-containing waste from industry, residences and businesses, and discharge a fraction of that received. A secondary factor in human exposure is the nature of the drinking water source- whether surface water or ground water. The presence or absence of fluorochemical compounds in ground water could provide additional information about migration of these chemicals through soil from point sources. For this study, then, a 2 x 2 matrix of cities was needed, based on primary sources and drinking water type.

The initial selection of test case cities was a pool of 30 cities. The first 26 cities were those with the highest 3M fluorochemical production/use volume in 1997. The remaining four cities were chosen as ones with generally lower uses of fluorochemicals. The 30 cities covered the majority of 3M business applications, including carpets, paper, textiles, apparel, and fluorochemicals production. Of the 30 test case cities, 15 used ground water as drinking water, and 15 used surface water for drinking water.

000291

The 30 cities were further divided on the basis of the ratio of the pounds of 3M fluorochemical compounds used in 1997 to the city's population. On the basis of this ratio, the 15 cities of each water source type were further divided into 3 groups of 5 each (for each water type), and designated as either a "high", "medium", or "low" ratio of fluorochemicals to population. This ratio will be used to assess the relative effects of primary and secondary sources, inasmuch as the source strength of secondary sources is usually population driven. The division of the 30 test case cities among these categories is listed in Table 2.

The study design called for a final selection of six test case cities. Because surface water is twice as prevalent as ground water (in the US) as the source of drinking water for cities, the selection of the six cities was similarly weighted thus, with four cities being surface water cases and two being ground water cases. Within each of the high ratio and medium ratio cities, the final selection of cities within each subgroup was a random selection, with the probability of choosing a city being weighted by the population size.

Six control cities were then randomly chosen to resemble the characteristics of the six study cities. Each control city would have the same water source type and approximately the same population as its corresponding study counterpart. To ensure similar population sizes between the study and control groups, city populations were separated into the following categories: 0-1000, 1000-5000, 5000-10000, 10000-25000, 25000-50000, 50000-100000, and greater than 100000. Cities from the 1990 U.S. Census Bureau data file were separated into six distinct groups for each study city's water source, region of the country, and population. Several potential control cities were randomly chosen from each subgroup to ensure the minimum distance of 50 miles from producing cities and a compatible water source type. The first city with the correct water source type and minimum distance was chosen as the corresponding control city. The probability of a particular city being picked varies when using this method. For example if there were 25 cities in the control city population, then the first city chosen would have had a 1 in 25 chance of being picked. If that city failed to meet the criteria, then the next city chosen would have a 1 in 24 chance of being picked, and so on.

City water sources, either ground or surface water, were determined from the U.S. Environmental Protection Agency Office of Ground Water and Drinking Water website (<http://www.epa.gov/ogwdw>). In addition, each control city was at least 50 miles from any city using or producing fluorochemical compounds. Distances between cities were calculated at <http://www.indo.com/distance>. Control cities were also chosen from a region of states with similar attributes. These regions are distinguished by the USEPA at <http://www.epa.gov/epahome/locate2.htm>. A file from the U.S. Census Bureau containing all cities in the United States and their 1990 populations was downloaded from the Census Bureau website and used as the list from which potential control cities were chosen <http://ftp.census.gov/ftp/pub/tiger/tms/gazetteer/places.zip>.

The twelve cities to comprise the Multi-City study (six test study cities and six control cities) are listed in Table 3. The six test cities represent two cases of carpet industry fluorochemical use (Dalton and Pensacola), two cases of paper industry fluorochemical use (Mobile and Kaukauna), one of apparel and textile fluorochemical use (Spartanburg), and one manufacturing production site (Decatur). The first round of sampling was conducted at three pairs of cities (six cities):

- Pensacola, FL and Port St. Lucie, FL
- Mobile, AL and Columbus, GA
- Decatur, AL and Cleveland, TN

The three test cities represent the three major 3M businesses: carpets (Pensacola), paper (Mobile), and manufacturing (Decatur). The initial round of sampling in these six cities is expected to form a compact pilot study for defining approximate environmental levels for this geographic region, and can be used as the basis for developing and testing further hypotheses.

**Table 1. Sample media to be collected in each city**

| <b>Matrix</b>                                      | <b>Quantity per sample</b> | <b>Replicates</b> |
|----------------------------------------------------|----------------------------|-------------------|
| Urban air                                          | 12 hr at 250 L/min         | 1                 |
| Drinking water plant intake                        | 1L                         | 3                 |
| Drinking water plant outflow                       | 1L                         | 3                 |
| Tap water at retail establishments                 | 1L                         | 3                 |
| Surface water (upstream of drinking water plant)   | 1L                         | 3                 |
| Sediment associated with surface water             | 200 g                      | 3                 |
| Surface monolayer at surface water collection site | 1L                         | 3                 |
| Fish at surface water collection site              | As available               | 2-10              |
| POTW influent (only post chlorination)             | 1L                         | 3                 |
| POTW sludge                                        | 200 g                      | 1                 |
| POTW effluent                                      | 1L                         | 3                 |
| Landfill leachate                                  | 1L                         | 3                 |
| Food from 3 local grocery store chains             |                            |                   |
| Ground beef- high fat                              | 1 lb                       | 3                 |
| Pork- moderate fat                                 | 2 chops                    | 3                 |
| Chicken- low fat                                   | 2 breasts                  | 3                 |
| Hot dogs- beef/pork mixture                        | 1 package                  | 3                 |
| Regional fish                                      | 0.5-1 lb                   | 3                 |
| Eggs                                               | ½ dozen                    | 3                 |
| Milk                                               | 1 quart                    | 3                 |
| Bread-white                                        | 1 loaf                     | 3                 |
| Green beans                                        | 1 package                  | 3                 |
| Apples- fresh                                      | 2                          | 3                 |
| Organic bread or flour                             | 1 lb                       | 1                 |

**Table 2. Potential Test Study cities, categorized by water source and ratio of population to industrial use of 3M fluorochemical compounds (FC)**

| Water Source | Ratio Group | City             | State | Pounds of FC Solids Used | 1990 US Census Population | Ratio  | Percent Chance of Being Chosen |
|--------------|-------------|------------------|-------|--------------------------|---------------------------|--------|--------------------------------|
| Ground       | High        | Cordova          | IL    | --                       | 638                       | --     | 0.9                            |
|              |             | Parchment        | MI    | 295,000                  | 1,958                     | 150.66 | 2.9                            |
|              |             | Riegelwood       | NC    | 14,000                   | 500                       | 28.00  | 0.7                            |
|              |             | Rittman          | OH    | 133,000                  | 6,147                     | 21.64  | 9.1                            |
|              |             | Pensacola        | FL    | 1,128,000                | 58,165                    | 19.39  | 86.3                           |
|              | Middle      | St. Francisville | LA    | 25,000                   | 1,700                     | 14.71  | 2.4                            |
|              |             | Rhineland        | WI    | 87,000                   | 7,427                     | 11.71  | 10.6                           |
|              |             | Prairie du Chien | WI    | 48,270                   | 5,659                     | 8.53   | 8.0                            |
|              |             | Kaukauna         | WI    | 54,000                   | 11,982                    | 4.51   | 17.0                           |
|              |             | Elkhart          | IN    | 84,660                   | 43,627                    | 1.94   | 62.0                           |
|              | Low         | Milford          | NJ    | 21,000                   | 15,990                    | 1.31   | 19.8                           |
|              |             | Walpole          | MA    | 18,000                   | 20,212                    | 0.89   | 25.0                           |
|              |             | Devers           | TX    | 55.25                    | 318                       | 0.17   | 0.4                            |
|              |             | Norco            | LA    | 441.28                   | 3,385                     | 0.13   | 4.2                            |
|              |             | Texas City       | TX    | 697                      | 40,820                    | 0.02   | 50.6                           |
| Surface      | High        | Dalton           | GA    | 2,700,000                | 21,761                    | 124.08 | 19.4                           |
|              |             | Jay              | ME    | 223,000                  | 5,080                     | 43.90  | 4.5                            |
|              |             | Social Circle    | GA    | 36,000                   | 2,755                     | 13.07  | 2.5                            |
|              |             | Port Huron       | MI    | 68,000                   | 33,694                    | 2.02   | 30.1                           |
|              |             | Decatur          | AL    | 92,452                   | 48,761                    | 1.90   | 43.5                           |
|              | Middle      | Augusta          | GA    | 82,052                   | 44,639                    | 1.84   | 13.5                           |
|              |             | Spartanburg      | SC    | 40,488                   | 43,467                    | 0.93   | 13.2                           |
|              |             | Mobile           | AL    | 175,458                  | 196,278                   | 0.89   | 59.5                           |
|              |             | Lumberton        | NC    | 14,100                   | 18,601                    | 0.76   | 5.6                            |
|              |             | Rochester        | NH    | 12,000                   | 26,630                    | 0.45   | 8.1                            |
|              | Low         | Greensboro       | NC    | 29,515                   | 183,521                   | 0.16   | 7.2                            |
|              |             | Erie             | PA    | 14,000                   | 108,718                   | 0.13   | 4.3                            |
|              |             | Milwaukee        | WI    | 61,065                   | 628,088                   | 0.10   | 24.7                           |
|              |             | Philadelphia     | PA    | 40,000                   | 1,585,577                 | 0.03   | 62.4                           |
|              |             | Linden           | NJ    | 216.75                   | 36,701                    | 0.01   | 1.4                            |

**Table 3. Final selection of Test Study and Control Cities**

| Water Source | Ratio Group | Study/Control | City           | State | 1990 Census Population |
|--------------|-------------|---------------|----------------|-------|------------------------|
| Ground       | High        | Study         | Pensacola      | FL    | 58,165                 |
|              |             | Control       | Port St. Lucie | FL    | 55,866                 |
|              | Middle      | Study         | Kaukauna       | WI    | 11,982                 |
|              |             | Control       | Englewood      | OH    | 11,432                 |
| Surface      | High 1      | Study         | Dalton         | GA    | 21,761                 |
|              |             | Control       | Greeneville    | TN    | 13,532                 |
|              | High 2      | Study         | Decatur        | AL    | 48,761                 |
|              |             | Control       | Cleveland      | TN    | 30,354                 |
|              | Middle 1    | Study         | Mobile         | AL    | 196,278                |
|              |             | Control       | Columbus       | GA    | 178,681                |
|              | Middle 2    | Study         | Spartanburg    | SC    | 43,467                 |
|              |             | Control       | Bowling Green  | KY    | 40,641                 |