A SURVEY OF COMMUNITY WATER FLUORIDATION IN THE UNITED STATES

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Abstract

The geographic distribution of community water fluoridation (CWF) in the U.S. was surveyed using data for states, counties, and water systems. The distribution of CWF is not uniform within states and CWF is not available to many small or rural communities. Explanations for geographic variations in CWF were sought by performing quantitative analysis using variables related to the perceived need for fluoridation (percent of counties without a dentist, prevalence of caries, poverty, and Medicaid eligibility) and barriers to its adoption (rurality, population size). Need was not found to be a factor in the adoption of CWF. The results of fluoridation decisions made between 1980 and 2008 were also analyzed to determine the effect of fluoridation decision-making structures. The type of authority was not found to be a predictor of the outcomes of fluoridation votes. A survey of the dental directors of each state was also conducted regarding states' support for CWF. The survey results indicated that states use a variety of means to promote CWF. Dental directors perceived community opposition and public apathy to be the greatest barriers to adoption of CWF. Recommendations for the future promotion of CWF and suggestions for further research are outlined.

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1. INTRODUCTION AND REVIEW OF THE LITERATURE

This thesis will examine the geographic distribution of community water fluoridation (CWF) in the United States and explore possible explanatory variables related to the adoption of CWF. Fluoridation of public water supplies has been promoted by public health agencies and dental professionals as a low-cost means of preventing dental caries since the 1950s. Water fluoridation was first begun in the U.S. in the mid-1940s. Within a few years, it had become a very controversial issue due to concerns about negative health effects from exposure to fluoride and arguments portraying fluoridation as a violation of civil liberties. After a steady increase in the adoption of water fluoridation, the rate of adoption leveled off in the 1980s. In 1985, 61 percent of the population used fluoridated water (Fluoridation census 1985). By 2006, an estimated 69.2 percent of the U.S. population using public water supply systems had access to a fluoridated water supply (Bailey, Barker et al. 2008).

I was born in a community (Plainview, Texas) that has a naturally fluoridated water supply. When I was a small child, my parents purchased bottled water for my sister and me to drink so that we would not experience dental fluorosis, the tooth mottling characteristic of people who consume water containing fluoride in a concentration over 1.0 parts per million (ppm). I grew up happily ignorant of the fact that fluoridation is controversial; I believed that fluoridation of water was natural, normal, and ubiquitous. It wasn't until 1987, when I happened to attend a city council meeting in San Antonio where fluoridation was being considered, that I realized what an extremely controversial issue it was. I observed a city council member, Helen Dutmer, tearfully proclaim that her son had not fought and died in Vietnam in order for the water to be fluoridated!

The fight over fluoridation in San Antonio, Honolulu, and other cities has since intrigued me on many levels. When I initially began my research on this topic, I considered myself firmly pro-fluoridation, and I still admit to a pro-fluoridation bias. However, I have also learned that there are legitimate arguments against CWF and that the need for fluoridation has sometimes been assumed.

This study is an attempt to understand why some states have generally been more successful in achieving high levels of fluoridation. Many communities have looked to fluoridation to reduce dental caries among their citizens, especially those who lack access to dental care. Local communities need to determine the most effective methods for improving dental health. Because any effort to improve dental health is likely to require a significant expenditure of financial and other resources, understanding the dynamics of the adoption of fluoridation may help to guide activities in this area to the most effective measures. Fluoridation may not be the best solution for some communities, and the resources that have been devoted to promoting fluoridation might be used more effectively to develop and test other measures to reduce caries such as dental sealants, fluoride mouthrinses, fluoride varnishes, and vaccines to prevent caries (NIDCR/CDC Dental Oral and Craniofacial Data Resource Center 2002).

Most of the growth in CWF occurred in the 1950s and 1960s, but the rate of adoption began to slow in the 1970s and has continued to be modest. In 1991, the U.S. Department of Health and Human Services established a goal that 75 percent of the population using public water supplies would have access to fluoridated water by 2000. This goal was not attained in 2000, so it was renewed as a goal for 2010 (2000). It seems very unlikely that the 75 percent goal will be reached by 2010, either.

In this introductory chapter I present a review of two bodies of literature that were influential in my approach and choice of variables: 1) studies about the adoption of public policy innovations, and 2) research on the adoption of CWF. Next, the following three chapters describe three approaches I used to explore the reasons for geographic variations in the adoption of CWF. Chapter 2 is a review of issues surrounding the adoption of CWF and the availability of data related to fluoridation. I also explain the research questions suggested by the review. In Chapter 3, I describe the quantitative data chosen for analysis, the selection of statistical tests used, and the results. Chapter 4 presents the results of a survey I conducted of state oral health directors regarding states' support of CWF and their perceptions of barriers to its adoption. Finally, Chapter 5 presents a discussion of the information gleaned through these three investigations and my conclusions. Except as noted, I created all of the maps using ArcMap version 9.2. Statistical analyses were conducted using SPSS version 16.0.

1.1 Review of the literature

The body of literature that has provided a theoretical framework and background for the present research can be divided into two broad categories: literature on the adoption of public policy innovations and research on the reasons for adoption or non-adoption of fluoridation.

1.1.1 Literature on the adoption of public policy innovations

Countless studies examining the adoption of public policy innovations have appeared in a wide variety of disciplines, from agriculture to political science to marketing. One cannot discuss diffusion research without reference to the works of Everett Rogers, one of the most influential researchers on the diffusion of innovations. He developed a typology of diffusion research that summarizes the different channels into which research has flowed (Rogers 1995):

- Earliness of knowing about innovations
- Rate of adoption of different innovations in a social system
- Innovativeness
- Opinion leadership
- Diffusion networks
- Rate of adoption in different social systems
- Communication channel use

- Consequences of innovation

Rogers' intent was to provide a "map" of diffusion research with this typology. Innovativeness, opinion leadership, diffusion networks, and communication channels have been used to study fluoridation. Rogers further identified five attributes of innovations that explain variance in the rate of adoption: relative advantage, compatibility, complexity, trialability, and observability. Rogers went on to list other variables that affect an innovation's rate of adoption: the type of innovation decision (optional, collective, or authority); the communication channels used; the nature of the social system; and the extent of change agents' promotion efforts. Rogers' work suggests many possible research avenues that could be applied to the study of fluoridation. In the present study, his classification scheme for innovation decisions will be utilized to analyze the effects of decision-making structures in communities.

Geographers have a long history of research into diffusion of innovations. To give one example, Clark (1984) delineated three components of innovation diffusion:

- Process: the interaction of demand (need) and supply for an innovation
- Structural: how the innovation is related to broader structures in society
- Cultural: the perception of the meaning of innovations by individuals and communities

He pointed out that because of their emphasis on the role of scale and space in diffusion, geographers have much to contribute to the literature. Scale, in this thesis, refers to what Johnston (2000) refers to as *geographical scale;* that is, the nested hierarchy of geographic spaces, ranging from the individual to the global. Scale is a critical issue in the diffusion of fluoridation because of the interplay between the various geographic and administrative entities involved.

Geographers have examined areal variations in the implementation of social policy by studying a number of government programs. Examples of such analyses have been collected in Kodras & Jones' (1990) work, whose contributors studied geographic dimensions of welfare programs, housing policies, education, health policy, women's issues, health maintenance organizations, and the food stamp program. Kodras (1982) used a combination of the adoption perspective and the market and infrastructure perspective in diffusion of innovations to research the diffusion of welfare programs. She examined the motivation underlying the program, the structural organization of government diffusion agents, the strategies used in diffusing the program, and the need for government assistance in the targeted population. Her research sought to discover how funds were allocated and where programs were first implemented – in areas where the need was greatest or in areas where they were most likely to succeed. This approach may also be applied to understanding the adoption of CWF.

Ormrod (1990) suggested that we should study a community's receptiveness to diffusing innovations. Receptiveness is a concept derived from adaptation theory, which contends that innovations are adopted because they are deemed a suitable match for local conditions. Receptiveness is shaped by the following three characteristics. *Relevance* relates to the perception of the potential benefits of the innovation. *Access to resources* emphasizes the need to look at both costs and infrastructure to support the innovation. *Viability* relates to the survival of the innovation and its ability to compete with alternative solutions to the problem. Variations in local factors that affect receptiveness provide explanations for the diffusion pattern of many innovations (Kodras 1988; Meir 1988).

Other social scientists have studied public policy adoption using a variety of models. Feiock and West (1993) investigated a number of competing explanations for policy adoption using the case of curbside recycling. The models examined were:

- Need/responsive policymaking: Employment of need measures as a motivation for policy adoption
- Diffusion of innovations: Policies adopted as a result of the actions of other jurisdictions
- Political institutions: Effect of form of government in terms of centralization and representation
- Federalism: State influence on local communities
- Interest group influence: Effect of interest groups on policy adoption
- Economics: Community affluence as a factor in policy adoption
- Administrative capacity: Importance of knowledge and technical expertise in policy adoption

Their methods for devising measures for each of these models may be questioned as oversimplifications. For example, they measured interest group influence through local membership in two national environmental organizations, thereby ignoring local interest groups that may have been influential. They determined that the models with the best predictive power were the Need/Responsiveness model, the Federalism model, and the Economic model.

Some researchers have investigated innovativeness as a characteristic of states and cities. For example, Walker (2006) looked at five types of innovations in cities in Britain. He concluded that innovations are too complex to be comparable, so adoption of one innovation is not a predictor of the adoption of other innovations.

Sapp and Korsching (2004) examined the effects of negative information and opinion leaders on acceptance of food irradiation, a controversy in many ways similar to water fluoridation. Their results indicated that while negative information was initially a powerful influence on the public, over time the statements of opinion leaders carried greater weight. Sapp and Korsching's model promotes the importance of longitudinal studies, which treat time as a variable and allow researchers to measure the effect of different lengths of exposure to influences.

Characteristics of local campaigns such as the presence of regional associations, the rise of interest groups, and local government structure were examined by Godwin and Schroedel (2000) in their study of gun control laws in California. In particular, they found that newly created interest groups providing new perspectives on the problem were influential with local governments. They also emphasized the importance of focusing events and the role of public health advocacy in the gun control controversy. This thesis will use several measures to investigate the influence of government structure and the influence of public officials on the adoption of fluoridation.

1.1.2 Literature on the adoption of water fluoridation

Numerous studies, mostly in the sociology or public health literature, have attempted to draw conclusions about characteristics of successful pro-fluoridation campaigns and the barriers to adoption. I have not attempted to review all of them here; rather, I selected representative studies for discussion. Motz's (1971) review article detailed the various approaches of social scientists who studied fluoridation during its first two decades. She classified the resulting body of research into the following categories: 1) demographic characteristics; 2) attitudes; 3) ideologies; 4) social movements; 5) decision-making processes; and 6) recommendations for successful campaigns. She determined that although demographic studies were inconclusive, studies of attitudes indicated that lack of knowledge about fluoridation was a significant factor in pro-fluoridation voting. In other words, the more information voters had about CWF, the less likely they were to favor it. Motz noted that research concerned with ideology provided some explanation for behavior in fluoridation referenda in terms of individual feelings of alienation from the political process or an "anti-science attitude." Her main criticism of case studies of fluoridation as a social movement was lack of a theoretical model. The important conclusion from research on decision-making processes, according to Motz, was that more educated communities with higher incomes were more likely to give rise to opposition groups. In discussing recommendations for successful adoption campaigns, she observed that, "The preoccupation with the question of fluoridation failure has introduced a myopia that magnifies the significance of fluoridation in the life of the average citizen" (p. 360). In other words, if fluoridation is unknown or unimportant to people, they are not likely to participate in pro-fluoridation campaigns or go out of their way to vote in fluoridation referenda.

Subsequent research has tended to follow the categories outlined by Motz. For example, Groth's dissertation presented case studies of the relationship between science and public policy in two issues: air pollution control and water fluoridation (Groth 1973). He concluded that issues of science were unimportant in fluoridation campaigns. Significant factors in the adoption of fluoridation included the amount of money spent on the campaign, the skill of campaign leaders, the quantity of advertising, and the emotional content of the arguments used.

One of the first important papers on the diffusion of fluoridation was Robert Crain's (1966) study of the spread of fluoridation among cities. He concluded that cities influenced each other because citizens and decisionmakers who were confused about conflicting claims took adoption or rejection by neighboring cities into account in their decisions. A criticism of Crain's research is that he assumed that the perceived need, or demand, for fluoridation did not vary among communities, when in fact there may be considerable variation in oral health, the organization of water systems, alternatives to water fluoridation, and other factors affecting demand. In a subsequent study, Wong (1978) tested the applicability of

Crain's model, which examined the diffusion of fluoridation among large cities, by studying small communities in Nebraska and concluded that Crain's results were not necessarily applicable to smaller areas. She suggested that population size is a significant determinant of fluoridation status, a point that will be addressed in this thesis.

Crain and Rosenthal (1966) examined the relationship between form of government and adoption of fluoridation. Relevant to the present study is their observation that city governments in the West are more likely to be non-partisan and have a city manager form, which they attributed to greater "progressivism" in the West. How progressivism translated into lower rates of fluoridation adoption was not addressed. Smith (1979) demonstrated that adopting communities tend to have greater centralization of authority in municipal government. The Community Power Structure Hypothesis (Hastreiter 1983) also states that there is a positive relationship between a centralized government structure and likelihood of adopting fluoridation. The relationship between fluoridation decisions and the type of authority used will be investigated in the present study.

Many papers have presented the results of case studies of fluoridation campaigns. For example, Mueller (1966) used a case study approach to examine referenda on fluoridation in seven California cities. He concluded that anti-fluoridation campaigners had an easier time convincing voters to reject fluoridation because all they had to do was create doubts about the safety of fluoridation. Another case study of sixteen referenda in Massachusetts (Frankel and Allukian 1973) examined several factors: level of political activity in each referendum; voter turnout; population size; political party affiliation; and income. The authors determined that the level of activity for and against fluoridation was the only significant factor in all of the referenda. A more recent case study suggested that greater urbanization, larger immigrant populations, voter apathy, and the decline of print media were partly responsible for the lack of success in pro-fluoridation campaigns, particularly in the West (Neenan 1996).

Frazier's (1980) review of research on fluoridation in the 1970s categorized research topics thus: 1) social psychological explanations; 2) community social and political structures and processes; 3) activities of leaders and groups; 4) communication about fluoridation; and 5) the influence of mass media. In discussing social psychological explanations, she remarked on a hypothesis that opponents of fluoridation do so because they perceive that fluoridation is not natural, and she questioned why no attempt had been made to portray fluoride as natural in fluoridation campaigns. Frazier concluded that fluoridation was more likely in communities with centralized decision-making structures and in cities where profluoridationists outcampaigned opponents. She drew from research into communication about fluoridation that there are significant differences between pro- and anti-fluoridationists' sources of information. Frazier stated that extensive media coverage of fluoridation was more likely to result in referenda being required for fluoridation decisions. In her conclusion, she also made a number of suggestions for further research: research on fluoridation as a process; longitudinal surveys; natural experiments; research on collective behavior; network analyses of influence; state political structure and process; optimal conditions for the promotion of fluoridation; and multidisciplinary research. Finally, Frazier made the intriguing observation that a trend toward individual responsibility for health and a declining emphasis on community public health measures may have affected the adoption of fluoridation.

Another line of research has related the adoption of fluoridation with the availability of funding for equipment and personnel. One study found a correlation between increased adoption of fluoridation and the presence of a full-time coordinator of fluoridation activities. In contrast, states that had small increases or declines in the number of people on fluoridated water were those that had not received federal or state support for fluoridation programs (Easley 1990). Similarly, a decline in funding available for fluoridation programs was observed in several states, including California, in the early 1980s after categorical funding for public health measures was replaced by block grants to states during the Reagan admistration ("Fluoridation suffers under block grant program" 1983).

Another approach has been to view fluoridation as a social movement rather than an innovation. Leahy and Mazur (1980) developed a model of the rise and fall of public opposition to four social movements: opposition to anti-ballistic missiles, the anti-nuclear power movement, the anti-abortion movement, and the anti-fluoridation movement. The authors concluded that peaks in the opposition to social movements coincided with increased media coverage. In addition, opposition to fluoridation corresponded with fears about communism and socialism and concerns over the health effects of trace "poisons," including DDT, mercury, and fluoride. There is still much concern about the health effects of various substances like pesticides and mercury. In fact, many anti-fluoridationists are also engaged in opposition to pesticides, amalgam dental fillings containing mercury, and vaccines that use mercury as a preservative (Fluoride Action Network 2008).

Martin (1988), in theorizing the role of scientific knowledge in controversies, examined resources available to pro- and anti-fluoridationists. He concluded that in countries where fluoridation has been widely adopted, pro-fluoridationists have been very successful in preventing opponents from being taken seriously. He argued that previous studies of fluoridation implicitly assumed that fluoridation is desirable and rational, and that opponents were therefore irrational. In Martin's view, pro-fluoridationists should be subjected to the same sort of critical analysis to which opponents have been. Some have argued that this emphasis on CWF has been detrimental to other measures that may be more effective, such as fluoride rinses or varnishes. Martin has argued that once PHS had decided to promote fluoridation, no alternatives were considered. The ingestion of fluoride was seen as more effective than other delivery methods, so PHS settled on fluoridation as "*the* prescription for better health" and dissent was not tolerated (Martin 1988).

In a similar vein, Reilly (2001) contended that the arguments of opponents of fluoridation have been given short shrift and that the concerns of opponents, rather than representing the fringe, tend to mirror the mainstream views of average Americans.

It appears that geographers have contributed relatively little to the existing literature on water fluoridation. Geographical research into water fluoridation in the 1970s is represented by an Ohio State University study of the diffusion of several innovations, including fluoridation, to cities in the contiguous U.S. (Herr, Agnew et al. 1976). The researchers investigated a number of demographic and social variables such as population, race, education, form of government, income, and proximity, and categorized them as representative of four constructs: information level, political culture, political structure, and need for the innovation. Their results indicated that population size matters, that the level of perceived need for the innovation is significant, and that the existence of a central propagator vs. local initiative was a factor in adoption. These variables will be investigated further in this study.

A recent research study by Nash (2003) utilized actor-network theory to examine the influence of actors like the Public Health Service and pro-fluoridation dentists on the adoption of fluoridation by two cities in Pennsylvania. Actor-network theory (ANT) seeks to understand the relationship between nature and culture by examining linkages between space and both human and non-human actors (Thrift 2000). Nash used ANT to contextualize the linkages among actors, including fluoride itself, and between actors and other movements. Two of Nash's conclusions should be underscored. First, she demonstrated the importance of pro- and anti-fluoridation groups' activities in fluoridation controversies. Second, she contended that fluoridation has been "black-boxed" as a solution to the problem of children's dental health and suggested that reliance on fluoridation could, in fact, be an indication of a failure of public health in the U.S.

2. BACKGROUND AND SURVEY OF RELEVANT DATA

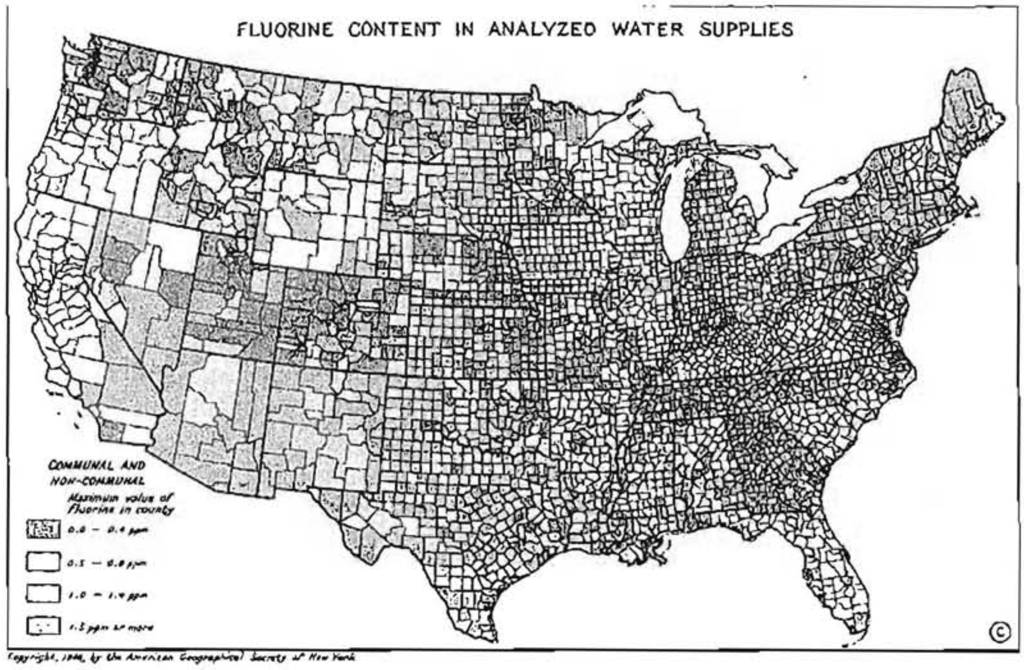
2.1 A description of fluoride

Fluoride is a mineral found in varying quantities, from 0.05 ppm to over 4 ppm, in most drinking water in the United States (McClure 1970). Fluoride comes from the element fluorine, which is present in rocks and soil in the form of fluoride compounds. When water passes over fluoride-containing rocks, the interaction creates fluoride ions, which are then carried in water (American Dental Association 2005). At concentrations of 0.7 to 1.2 ppm, water is said to be *optimally* fluoridated for the purpose of reducing tooth decay, whether the fluoride is present naturally or added. Community water fluoridation (CWF) is the practice of adding fluoride to public water supplies with a fluoride concentration lower than 0.7 ppm to bring it to the optimal level. A range of concentrations is used to define optimal levels because of geographic and seasonal variations in the amount of water that people typically consume. Water that contains less than 0.6 ppm of fluoride is termed *suboptimally* fluoridated.

A study conducted in 1946 produced a map (Figure 2-1) showing the levels of naturally occurring fluoride in both public and non-public water supplies (Van Burkalow 1946). One can see that the fluoride content of water supplies in many areas of the U.S. had not been determined by the time of the study. The map shows that the distribution of naturally fluoridated water was concentrated mostly in states west of the Mississippi, the upper

Midwest, and eastern Virginia and Maryland. The current distribution of naturally fluoridated water supplies will be discussed in Section 2.5.2.

Figure 2-1. Fluorine Content in Analyzed Water Supplies



In 1992, four percent of the U.S. population received optimally naturally fluoridated water ("Populations receiving optimally fluoridated public drinking water -- United States, 2000" 2002). An interesting question that has been raised is whether communities whose water supplies have some natural fluoride, but not at optimal levels, feel that it is unnecessary to adjust the fluoride levels of their water. Spears (1979) argued that water supplies in Southwestern states that had 70 percent of the optimal level of fluoride should be counted as optimally fluoridated. According to Spears, hundreds of communities would be included in the list of water systems with optimally naturally fluoridated water if the definition of "optimally fluoridated" were changed. It has also been suggested that water systems with fluctuating fluoride levels may have decided that fluoridation is too burdensome because constant testing and adjustment are required (Chan, Montgomery et al. 1993).

Water containing fluoride at more than 1.5 ppm is considered *excessively* fluoridated. The U.S. Environmental Protection Agency (EPA) requires the removal of excessive fluoride if the concentration is 4.0 ppm or higher (American Dental Association 2005).

Fluoride is added to water in the form of fluorosilicic acid (FSA), sodium fluorosilicate, or sodium fluoride (Centers for Disease Control 2008b). FSA is the most commonly used fluoride additive and is primarily a by-product of the manufacture of fertilizer. Sodium fluorosilicate and sodium fluoride are usually manufactured from FSA. A more detailed discussion of these fluoride additives is in Section 2.7.3.

2.2 The discovery of fluoride's role in preventing cavities

The story of fluoride's connection to oral health began early in the 20^{th} century, when a dentist named Frederick McKay began investigations into brown stains on the teeth of residents of Colorado Springs, Colorado (McClure 1970). In 1915, researchers discovered that the brown stains only occurred when children's teeth were developing; once a person's teeth had calcified without the stains, he or she was no longer at risk for developing staining. Staining was later observed on people's teeth in other parts of the country, such as Oakley, Idaho and Bauxite, Arkansas. When these communities later changed their water supply sources, water was confirmed as the source of the brown stains. In 1931, fluoride was determined to be the cause of "Colorado Brown Stain," now known as dental fluorosis.

Further research was initiated in 1931 to determine how much fluoride had to be present in water for fluorosis to occur. Researchers eventually established that fluoride at a level of up to 1.0 ppm did not cause fluorosis. A comparison of the geographic pattern of fluorosis and the prevalence of dental caries indicated an inverse relationship. The southwestern United States was observed to have a higher incidence of dental fluorosis while having lower rates of dental caries (McClure 1970). In the early 1940s, researchers investigated the inverse relationship between the fluoride content of the public water supply and prevalence of dental caries in children (Dean, Arnold et al. 1942). They concluded that fluoride at a concentration of 1.0 ppm reduced the incidence of dental caries while causing little or no dental fluorosis.

As early as 1939, oral health researchers had suggested adding fluoride to drinking water in areas where its natural occurrence was low in order to decrease tooth decay (McClure 1970). Several communities (Grand Rapids, Michigan; Newburgh, New York; Brantford, Ontario; Sheboygan, Wisconsin; Evanston, Illinois; Midland, Michigan; Lewiston, Idaho; and Marshall, Texas) decided to commence testing of water fluoridation between 1944 and 1947. Subsequently, Grand Rapids became the first city in the United States to add fluoride to its public water supply. After 11 years of observation, researchers determined that the incidence of dental caries had been reduced by about 60 percent in children born in the test communities after fluoridation was begun.

Interestingly, the addition of fluoride has been characterized as the adjustment or correction of fluoride deficiency, as if optimal levels of naturally-occurring fluoride in drinking water were the norm (American Dental Association 2005). Table 2-1 shows the percent of the U.S. population drinking naturally fluoridated water. Clearly, the presence of naturally-occurring fluoride in drinking water at a level of 0.7 ppm or higher is not the norm. In fact, the number of people consuming naturally fluoridated water has declined in part because some water systems serving large populations (e.g., Dallas and Fort Worth, Texas) switched to unfluoridated sources of water (U.S. Division of Dental Health 1969). In some states, the population receiving naturally fluoridated water has declined significantly since 1985. Appendix F shows the percent of each state's population on public water supplies receiving optimally naturally fluoridated water in 1985 and 2005. Data for 2005 was not available for18 states.

Table 2-1. Percent of U.S. Population Receiving Optimally Naturally Fluoridated Water

Year	Percent of U.S. Population Receiving Optimally Naturally Fluoridated Water
1967	6.0
1985	7.4
1992	4.0

(McClure 1970; Fluoridation census 1985; NIDCR/CDC Dental Oral and Craniofacial Data Resource Center 2002)

Initially, fluoride was believed to cause changes in enamel during tooth development. Research has since indicated that the effect of fluoride is primarily topical rather than systemic. Fluoride enhances remineralization of tooth surfaces, inhibits demineralization, and inhibits bacterial activity in plaque ("Achievements in public health, 1900-1999: fluoridation of drinking water to prevent dental caries" 1999). Systemic fluoride in saliva also provides some protection against decay (American Dental Association 2005).

Following the success of water fluoridation in Grand Rapids, many communities throughout the U.S. began adding fluoride to public water supplies. Some states achieved widespread fluoridation in the three decades following the appearance of CWF; others have had much lower rates of adoption. Table 2-2 shows the percent of the population served by fluoridated water in each state from 1985 to 2005. Judging from press coverage of fluoridation debates, fluoridation as a public health measure appears to be much more controversial in some states (e.g. Massachusetts and New Jersey). In other states (e.g. Idaho), fluoridation appears not to have been considered much.

Table 2-2. Percent of State Population Receiving Fluoridated Water, 1985-2005

State	1985	1992	2005
Alabama	84.0	82.6	82.0
Alaska	77.0	61.2	57.3
Arizona	21.0	49.9	55.4
Arkansas	59.0	58.7	62.1
California	17.0	15.7	27.6
Colorado	97.0	81.7	75.4
Connecticut	92.0	85.9	87.6
Delaware	67.0	67.4	80.9
Florida	47.0	58.3	67.4
Georgia	96.0	92.1	93.0
Hawai'i	16.0	13.0	8.6
Idaho	34.0	48.3	47.5

State	1985	1992	2005
Illinois	97.0	95.2	99.1
Indiana	97.0	98.6	95.5
Iowa	87.0	91.4	91.3
Kansas	40.0	58.4	62.1
Kentucky	83.0	100.0	99.6
Louisiana	51.0	55.7	45.9
Maine	51.0	55.8	74.4
Maryland	96.0	85.8	93.7
Massachusetts	53.0	57.0	60.7
Michigan	91.0	88.5	86.2
Minnesota	81.0	93.4	98.4
Mississippi	47.0	48.4	46.1
Missouri	71.0	71.4	80.9
Montana	29.0	25.9	23.8
Nebraska	60.0	62.1	69.5
Nevada	2.0	2.1	69.4
New Hampshire	17.0	24.0	42.7
New Jersey	15.0	16.2	20.8
New Mexico	67.0	66.2	76.6
New York	70.0	69.7	72.9
North Carolina	75.0	78.5	84.6
North Dakota	95.0	96.4	95.6
Ohio	88.0	87.9	90.6
Oklahoma	60.0	58.0	74.6
Oregon	25.0	24.8	19.4
Pennsylvania	54.0	20.9	54.0
Rhode Island	80.0	100.0	89.2
South Carolina	93.0	90.0	91.4
South Dakota	94.0	100.0	78.0
Tennessee	80.0	92.0	96.0
Texas	60.0	64.0	65.7
Utah	2.0	3.1	2.2
Vermont	60.0	57.4	55.7
Virginia	85.0	72.1	93.8
Washington	41.0	53.2	58.9
West Virginia	65.0	82.1	91.5
Wisconsin	89.0	93.0	89.4

State	1985	1992	2005
Wyoming	29.0	35.7	36.7

(Fluoridation census 1985; "Populations receiving optimally fluoridated public drinking water -- United States, 2000" 2002; Centers for Disease Control n.d.)

In some states, fluoridation levels have declined since 1985, or declined and then increased. This may be explained by population growth in fluoridated or unfluoridated communities and by adding populations to public water supplies. Another possible explanation is that the methods of calculating the fluoridated population of each water system may have changed over time. The calculation of fluoridated populations will be discussed further in Section 2.8.

2.3 Perceptions of the need for fluoridation

One question to be addressed by the present research is whether need is a factor in the adoption of CWF. Perceptions of the need for CWF vary considerably depending upon whose views are being examined. Critics of fluoridation argue that the need for fluoridation has not been well-established. They assert that promoters of fluoridation fail to take into consideration the perceptions of the target population. Typically, when the members of a community are given the opportunity to state their needs and are given alternatives or are able to modify a technological innovation, they are more receptive to the innovation than when it is perceived as being imposed by external forces (Rogers 1995). This thesis will approach need from the perspective of fluoridation promoters.

The 1990 National Health Interview Survey asked respondents about their understanding of the purpose of CWF. Although 62 percent correctly identified the purpose of CWF as preventing tooth decay, the remainder either did not know its purpose or incorrectly believed fluoride was added to water for purification or some other reason (Centers for Disease Control). In addition, many individuals do not know whether their drinking water is optimally fluoridated (General Accounting Office 1979; Wagener, Nourjah et al. 1992).

While CDC and state oral health departments have continued to emphasize the importance of CWF in reducing caries, it has not been demonstrated that the general public perceives CWF to be the best solution. Most people believe that tooth brushing is the best way to prevent caries, and many do not know about CWF or understand its purpose. The Surgeon General's report on oral health (United States Department of Health and Human Services 2000) makes a critical point: "You cannot be healthy without oral health" (ch. 1). Yet, the report also notes that individuals' self-reported oral health satisfaction did not correlate with measures used by clinicians to rate the severity of dental caries or periodontal disease. It may not be a stretch to conclude that people simply do not give the same weight to dental caries that they do to other health concerns.

2.3.1 Prevalence of dental caries

The primary purpose of CWF is to reduce the incidence of dental caries. Caries is considered an important public health concern because it is the most common chronic disease in children, affecting 58.6 percent of children ages 5-17 (United States Department of Health and Human Services 2000). Figure 2-2 shows the geographic distribution of caries experience in third graders. Acute dental problems, including toothaches, resulted in over 1.6 million missed school days in 1996 (Holt and Kraft 2003). Missing teeth, extracted due to caries or periodontal disease, create difficulties in chewing as well as embarrassment due to the perception that missing teeth have a negative effect on appearance (United States Department of Health and Human Services 2000).

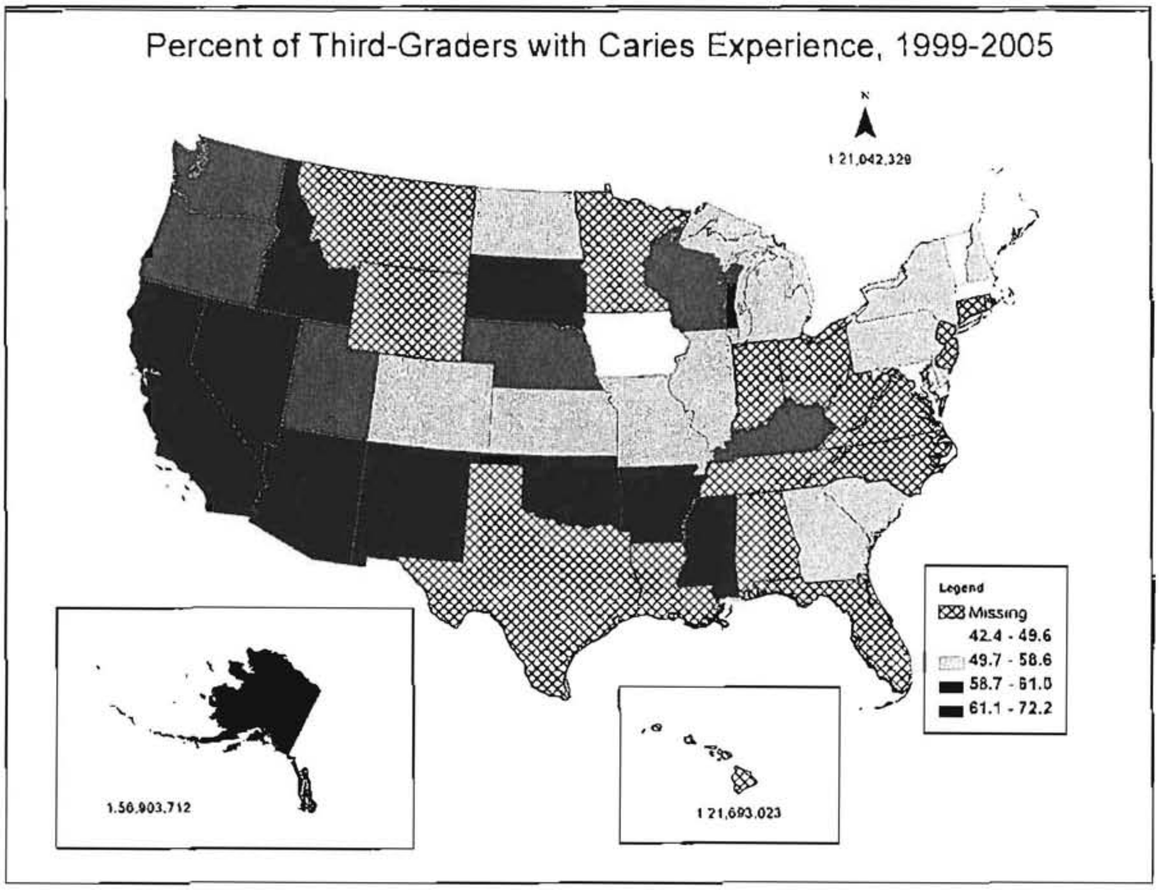


Figure 2-2. Percent of Third-Graders with Caries Experience, 1999-2005

Tooth decay has declined dramatically in the United States over the past four decades. The percent of children ages 12-17 who were caries-free in 1966 was about 11%. In 1991, the percent of caries-free children had increased to 33% (Milgrom and Reisine 2000). However, not all of the decline in the incidence of caries can be attributed to CWF. Initially, caries reduction due to CWF was estimated at 50 to 70 percent. By the mid-1980s, there was only an 18 percent difference in tooth decay between unfluoridated and communities with fluoridated water ("Achievements in public health, 1900-1999: fluoridation of drinking water to prevent dental caries" 1999). Several factors have contributed to the decline in caries in both fluoridated and unfluoridated communities. First, foods containing fluoride and products made with fluoridated water are consumed in unfluoridated communities. The popularity of bottled drinking water has increased dramatically over the past two decades. Studies have demonstrated that many brands of bottled water manufactured using fluoridated municipal water supplies happen to contain quantities of fluoride that are considered optimal for the prevention of dental caries (Johnson and DeBiase 2003). Furthermore, many common foods, especially tea, contain high levels of fluoride (Whyte, Essmyer et al. 2005), so people may consume considerable quantities of fluoride even when their municipal water supplies are not fluoridated. Second, the use of fluoride toothpaste has become prevalent ("Achievements in public health, 1900-1999: fluoridation of drinking water to prevent dental caries" 1999). Fluoride delivered in toothpaste and through other means has improved oral health in communities both with and without fluoridated water (Smith 1988; Hinman, Sterritt et al. 1996). Third, an increase in other environmental sources of fluorides such as mining and manufacturing may also play a role in declining tooth decay (Smith 1988). These improvements in oral health raise questions about the continued need for fluoridation.

Although public health officials and oral health practitioners believe that caries is a significant issue (United States Department of Health and Human Services 2000), Groth (1991) suggested that the average person does not view tooth decay as a serious health problem, and they are unable to "see" the benefits of fluoridation (or at least they do not see how the benefits outweigh the possible risks). The Surgeon General's report on oral health indicates that most Americans are satisfied with their oral health, although there are significant differences in response by ethnicity (United States Department of Health and Human Services 2000).

It is difficult to assess the relationship between the prevalence of caries and CWF. Higher caries incidence has been associated with lower levels of fluoridation (McClure 1970). On the other hand, some communities in New York have high incidences of caries in spite of having been fluoridated for decades (PR Newswire 2002). The last comprehensive review of the efficacy of CWF in the U.S. was published in 1991 (Ad Hoc Subcommittee on Fluoride 1991). It reviewed research done in a number of different countries and referenced studies done decades ago that may not be applicable today. The studies reviewed took place prior to the increased popularity of bottled water, and the most recent study of dietary intake of fluoride that was referenced was from 1980. The question this research will address is whether there is a discernable relationship between caries prevalence and CWF at the county level.

The prevalence of caries in children is measured by states in several ways, which makes it difficult to compare their data (Appendix C lists the measures of caries in children used by each state). A standard measure of oral health is the number of decayed, missing, or filled teeth (DMFT). Some states report data only in terms of decayed or filled teeth (DFT). The definition of children is also inconsistent among states. Children may include those between ages 6-17 or those aged between infancy and age 18. Some states survey the oral health of third graders; others survey health based on age groupings. Prevalence of caries may be reported as lifetime caries experience or untreated decay. Caries may also be reported as the mean number of DMFT per child, the mean number of teeth with untreated decay, or the percent of children who have either DFT or untreated decay. Furthermore, some states have not conducted oral health surveys on children in the past decade.

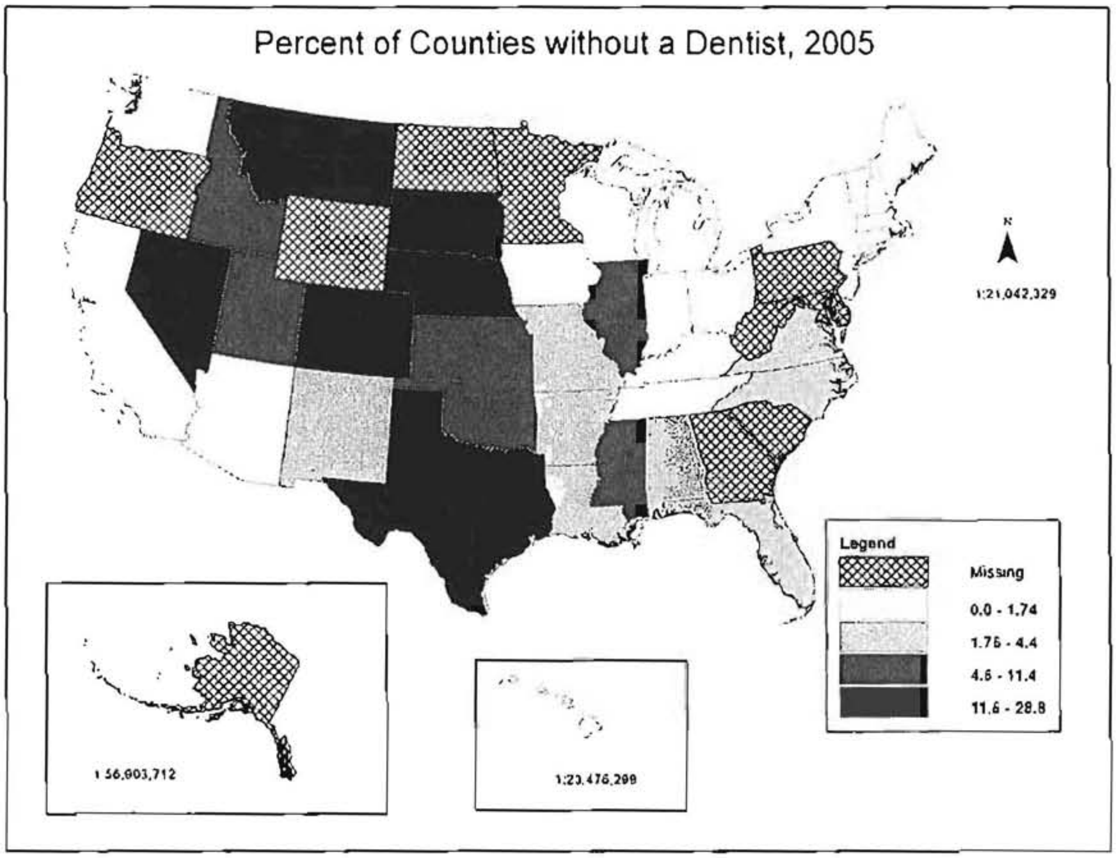
Data on the prevalence of dental caries among third-graders in 33 states was obtained from the Centers for Disease Control and Prevention (Centers for Disease Control, National Center for Chronic Disease Prevention and Health Promotion et al.). The most current information available for each state, derived from surveys done between 1999 and 2005, was used because states do not conduct oral health surveys annually. Seventeen states have not published survey data for third graders, so their data is missing. This lack of consistent data across states is being addressed by CDC, which provides funding to states for oral health surveys (Centers for Disease Control 2008a). Caries incidence may be affected by many practices, such as quality of oral hygiene, frequency of visits to an oral health professional, and diet, in addition to CWF (United States Department of Health and Human

Services 2000). This makes it difficult to draw any conclusions about the relationship between caries and CWF prevalence.

2.3.2 Access to dental care

Fluoridation has been promoted by states as a low-cost means of improving oral health in children who are not regularly seen by a dentist and as a way of reducing public expenditures on dental care for children. Although there may be many reasons why people do not visit dentists, ability to pay and proximity are two significant determinants of utilization (Alaska Oral Health Program n.d.). There are two primary measures of access to dental care: the availability of dentists and the availability of dental health insurance coverage. Figure 2-3 illustrates the percent of counties in each state that do not have dentists, and the data table is in Appendix E. I compiled the data from published synopses of state oral health programs (Centers for Disease Control National Center for Chronic Disease Prevention and Health Promotion 2005). Unfortunately, data on the geographic distribution of dentists or a list of the counties lacking dentists in each state is not available except for Ohio (Oral Health America 2003). In addition, 11 states have not reported this data to CDC.

Figure 2-3. Percent of Counties without a Dentist, 2005



Currently, there are 3,951 Dental Health Professional Shortage Areas (HPSA) in the U.S. HPSAs are areas designated by the Health Resources and Services Administration (Health Resources and Services Administration 2008). The boundaries of HPSAs are defined using the area served by health centers or by Census tracts. CWF data is available for water systems, whose boundaries do not generally correspond to HPSAs, so it would be difficult to use HPSAs to analyze the adoption of CWF.

Because of the difficulties in using HPSAs to investigate the relationship between CWF and lack of access to dental care, I have chosen to use data on children's eligibility for Medicaid or State Children's Health Insurance Program (SCHIP). Medicaid is a federal program to provide healthcare coverage to low-income individuals. Medicaid is administered by states, and each state maintains its own eligibility guidelines (Centers for Medicare and Medicaid Services 2006). SCHIP, a program to provide insurance funding for low-income children, is funded by both federal and state governments and is administered by states, which determine eligibility criteria (United States Department of Health and Human Services 2008). Few dentists participate in Medicaid, so families that rely on Medicaid for their children's health coverage are less likely to have access to affordable dental care (General Accounting Office 2000). SCHIP includes a component for dental coverage, but states vary in how they determine eligibility for dental services under SCHIP, and the services provided also vary (Centers for Medicare and Medicaid Services 2008). Appendix E shows the percent of children enrolled in Medicaid/SCHIP and the percent of dentists who accept Medicaid patients in each state. Figure 2-4 illustrates the geographic variation in Medicaid/SCHIP eligibility between states.

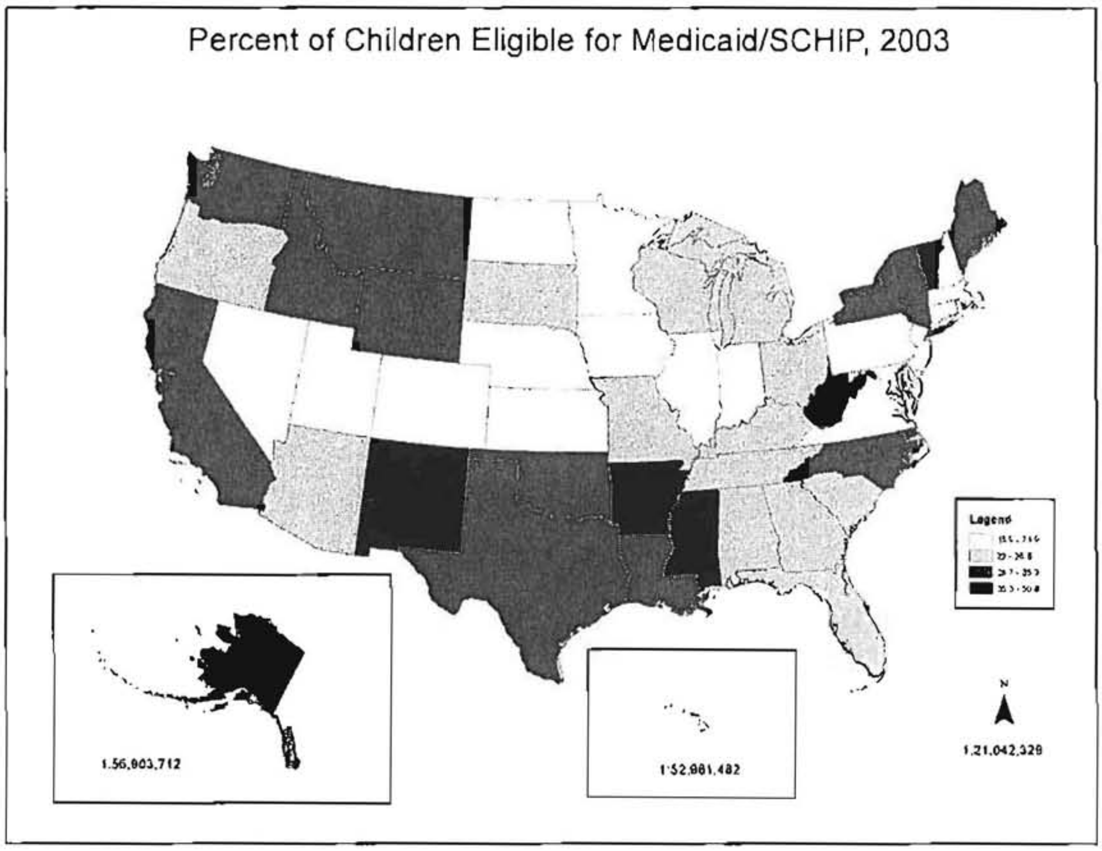


Figure 2-4. Percent of Children Eligible for Medicaid/SCHIP, 2003

2.4 Proponents and opponents

Water fluoridation has been hailed by oral health professionals as a major public health measure and vilified by opponents as the deliberate poisoning of the citizenry. Although I did not investigate the influence of interest groups on the adoption of fluoridation, it was mentioned as an important barrier by state dental directors in their survey responses (see Chapter 4). Thus, a brief overview of the situation is presented in this section.

The Centers for Disease Control has characterized CWF as one of the great public health achievements of the 20th century ("Achievements in public health, 1900-1999: fluoridation of drinking water to prevent dental caries" 1999). Opponents of CWF claim that fluoride is a toxic substance that may be responsible for many health problems (Reilly 2001; Fluoride Action Network 2008). At certain times and places, it has proven to be an extremely contentious issue (Reilly 2001). The oral health coordinator of one Western state confided to me that CWF was such a controversial issue in her state that it had generated death threats.

From the beginning, dentists and other oral health professionals have been the chief proponents of community water fluoridation. Some observers have wondered why, reasoning that if dental caries were to decrease significantly, dentists would lose business. The answer to this apparent contradiction is that dentists have adequate business without filling cavities or extracting decayed teeth. In addition, the supply of dentists is controlled by the credentialing and licensing process, and in many areas there are not enough dentists to meet demand (Martin 1991). One may presume, also, that it gives dentists no joy to fill cavities, especially those of small children, when dental caries can so easily be prevented. Yet, there may be a measure of self-interest in the promotion of fluoridation by dentists. Surveys have shown that dentists are reluctant to treat Medicaid recipients or poor patients who are perceived as being less likely to keep appointments or to maintain care of their teeth (General Accounting Office 2000; Alaska Oral Health Program n.d.). Critics have asserted that supporting fluoridation and other government-sponsored oral health programs is a means of shifting responsibility for these populations to government and away from the dental profession (Benn 2003).

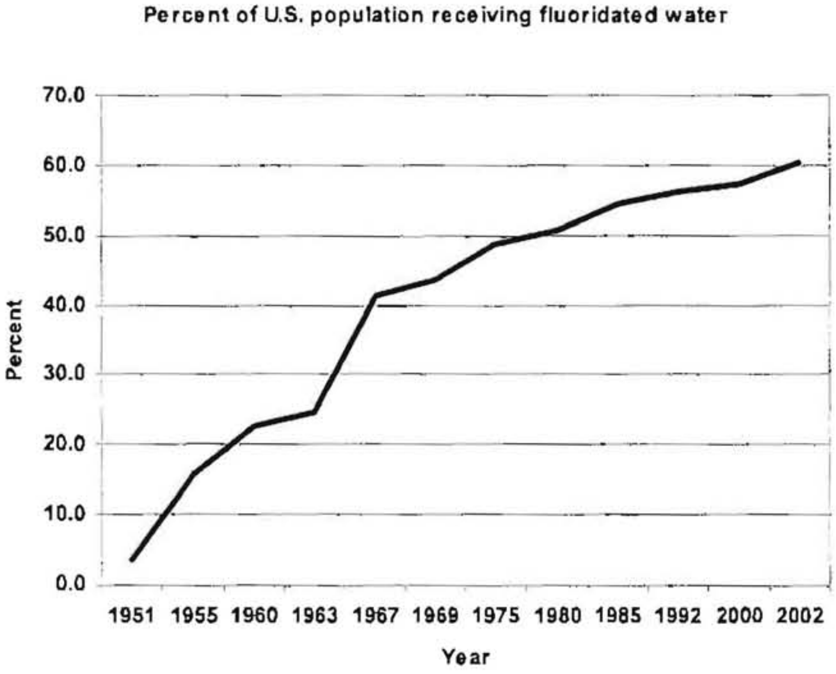
Although CWF initially faced virtually no opposition, by 1950 anti-fluoridation groups began to appear, and by the mid-1950's, fluoridation campaigns usually attracted opposition (Reilly 2001). Anti-fluoridationists have consistently cited health concerns and have claimed that fluoride is a carcinogen and a contributor to such conditions as Down syndrome, Alzheimer's disease, and autism (Fluoride Action Network 2008). Another major argument of anti-fluoridationists has been to depict fluoridation as mass medication and a violation of civil liberties. These arguments against fluoridation have remained virtually unchanged for over half a century. More recently, opponents have suggested that it is difficult to ensure the appropriate dosage of fluoride when people may be exposed to varying amounts of fluoride from a variety of sources. They have also pointed out that water supplies are not an effective means of providing fluoride, because the greatest benefit from fluoride is through its topical application rather than systemic exposure through consumption. Additionally, most fluoride added to water supplies is not consumed by humans and is returned to the environment. Furthermore, they argue that fluoridation is not effective and the decline in the prevalence of caries in the U.S. cannot be attributed to CWF (Fluoride Action Network 2008).

2.5 Geographic variation in community water fluoridation

2.5.1 The adoption of CWF

Figure 2-5 shows the growth of CWF in the United States. The proportion of people served by fluoridated water has continued to increase over the past 50 years, but the rate of adoption has slowed somewhat in the past 25 years.

Figure 2-5. Percent of U.S. Population Receiving Fluoridated Water



(National Center for Chronic Disease Prevention and Health Promotion 2007)

There is considerable geographic variation in the prevalence of community water fluoridation (CWF) in the U.S. Western states have a lower percentage of their populations using fluoridated public water supplies than do states in the East (Figure 2.3), and four of the five largest unfluoridated cities are in the West: San Jose, California; Portland, Oregon; Fresno, California (partial); and Honolulu, Hawai'i (the fifth is Wichita, Kansas).

This thesis has adopted CDC's categorization scheme for state fluoridation levels because it provides a convenient categorical variable for logistic regression analysis. The categories are outlined in Table 2-3 and are illustrated in Figure 2-6:

Table 2-3 CDC Fluoridation Categories

Category	Percent of Population Receiving Fluoridated Water
1	0-24%
2	25-49%
3	50-74%
4	75-100%

(Centers for Disease Control and Prevention)

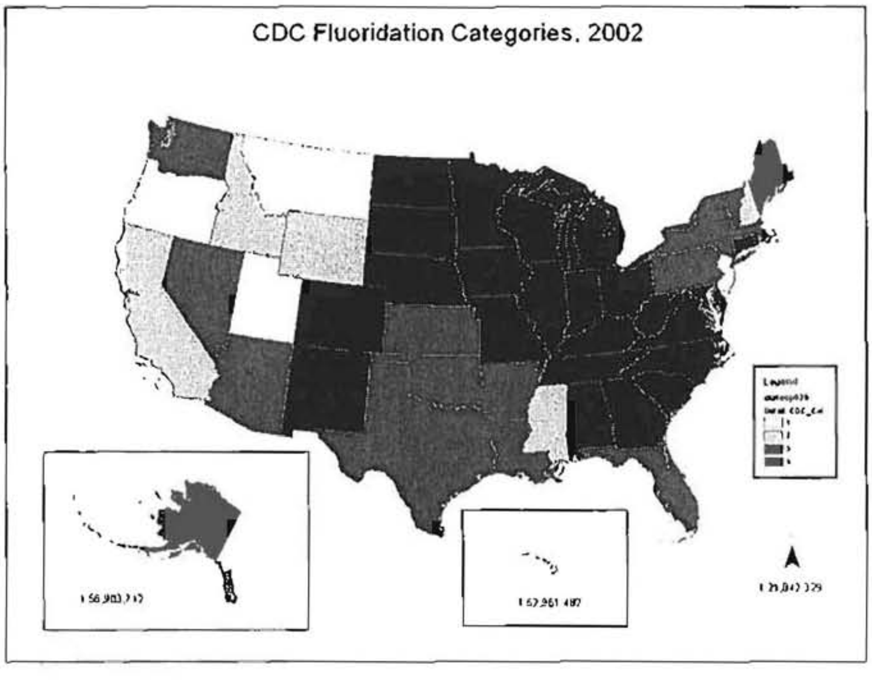


Figure 2-6. CDC Fluoridation Categories, 2002

One factor that affects the computation of the fluoridated population is the proportion of each state's population served by public water supplies, which ranges from 97 percent in Utah to 57 percent in Maine as of 2000 (Hutson, Barber et al. 2005) (the data for each state is listed in Appendix G). The proportion of the population whose water is naturally fluoridated at levels sufficient to prevent tooth decay also contributes to the total state population receiving optimally fluoridated water. The range is a low of 0.1 percent of the population receiving optimally naturally fluoridated water in Minnesota to a high of 27.4 percent in Idaho (Centers for Disease Control and Prevention 2001) (Appendix H lists fluoridation data for each state).

Furthermore, there are many other differences among states and how they have approached CWF since it first became available in 1945. There are variations in the degree to which state oral health departments have encouraged and supported CWF. These factors were explored in my survey of state dental directors. States also vary in the funding of CWF and other oral health measures and funding may have varied over time. The amount of funding and support available from the federal government has also waxed and waned. Funding for fluoridation will be discussed further in Section 2.7.

Another important determinant of the prevalence of fluoridation is state legislation. Several states have passed laws regulating how fluoridation decisions are made or mandating fluoridation in communities over a certain population threshold (see Appendix A). Other states have left fluoridation decisions entirely to cities, counties, health boards, or water boards. Statewide laws seem to be the most effective way to bring about the adoption of water fluoridation. States such as Illinois and Connecticut have achieved widespread fluoridation by virtue of having passed fluoridation mandates decades ago. On the other hand, Tennessee and North Dakota have achieved high adoption rates of fluoridation without statewide laws. Tennessee was able to achieve fluoridation of 96 percent of the population on public water supplies by providing funding to small water systems and hiring a full-time fluoridation engineer to provide education to water system operators (Collier 1976). In addition, the state Department of Health conducted an oral health needs assessment and used data on the prevalence of dental caries in unfluoridated areas to persuade local utility boards to implement fluoridation (Brumley 2001).

2.5.2 The spatial distribution of CWF

Most large cities in the United States have adopted fluoridation. Hence, the areas that have not adopted fluoridation tend to be smaller cities or less-populous rural areas. A few examples illustrate a range of success among states in fluoridating smaller communities:

- New Jersey is one of the least fluoridated states, with only 20.8 percent of the population on public water supplies receiving fluoridated water in 2002 (Centers for Disease Control 2002). Public health officials have explained this situation by pointing first to the large number of small water systems. They also blamed lack of support from the governor and active opposition by some officials in the New Jersey Department of Health (Bailey and Sicard 2008).

- Eighty-two percent of the population of Alabama on public water supplies receives fluoridated water. Alabama has not been able to obtain sufficient funding from its legislature to provide grants to small water systems for fluoridation. In 2000, the Alabama state health department had only one fluoridation coordinator to work with over 550 water systems (Rabb 2000).

- Ohio, with 91 percent of its population on public water supplies receiving fluoridated water, has a fluoridation reimbursement program to assist small water systems with startup costs (Ohio Department of Health 2007a).

Most states have focused fluoridation efforts mainly on urbanized areas and larger cities For example, California's state law, passed in 1995, requires fluoridation of water systems serving 10,000 people or more (Fine 1996). Water fluoridation is reported by CDC as a proportion of the total state population and the proportion of the population on public water supplies. However, if we examine the geographic extent of fluoridation, it is apparent that in many states, only a few water systems account for most of the population receiving fluoridated water. After the Las Vegas Valley (Nevada) Water District, which served 1,181,263 people, implemented fluoridation in 2000, the proportion of Nevada's state population receiving fluoridated water increased from 2.1 percent in 1992 to 65.9 percent in 2000(Centers for Disease Control and Prevention 2008). In New York state, New York City is 100 percent fluoridated, but the rest of the state is fluoridated at a level of approximately 45 percent (Reuther and Veschusio 2008). New York City's population, which represented 42 percent of the state population in 2000 (U.S. Census Bureau 2007), has a large effect on state fluoridation levels: 72.9 percent of the state population on public water supplies received fluoridated water in 2002 (Centers for Disease Control 2002). Rural counties are also less likely to have an adequate supply of oral health professionals, especially dentists (United States Department of Health and Human Services 2000). In 2000, an estimated 25 million Americans lived in areas lacking adequate dental care services. The pattern of adoption suggests that fluoridation has been adopted where it is easiest to implement, and it may not reach people who are less likely to have access to dental care and therefore would derive the greatest benefit from fluoridation. This study will examine fluoridation status as it is related to population size and rurality in order to gain a greater understanding of how successful CWF has been in reaching these populations.

Looking at the distribution of fluoridation at the county level provides a different picture of the success of states in implementing fluoridation. Figure 2-7 through Figure 2-9 illustrate the distribution of overall, adjusted, and natural fluoridation at the county level in states for which data was available. These maps show that the distribution of fluoridation is not uniform within most states.

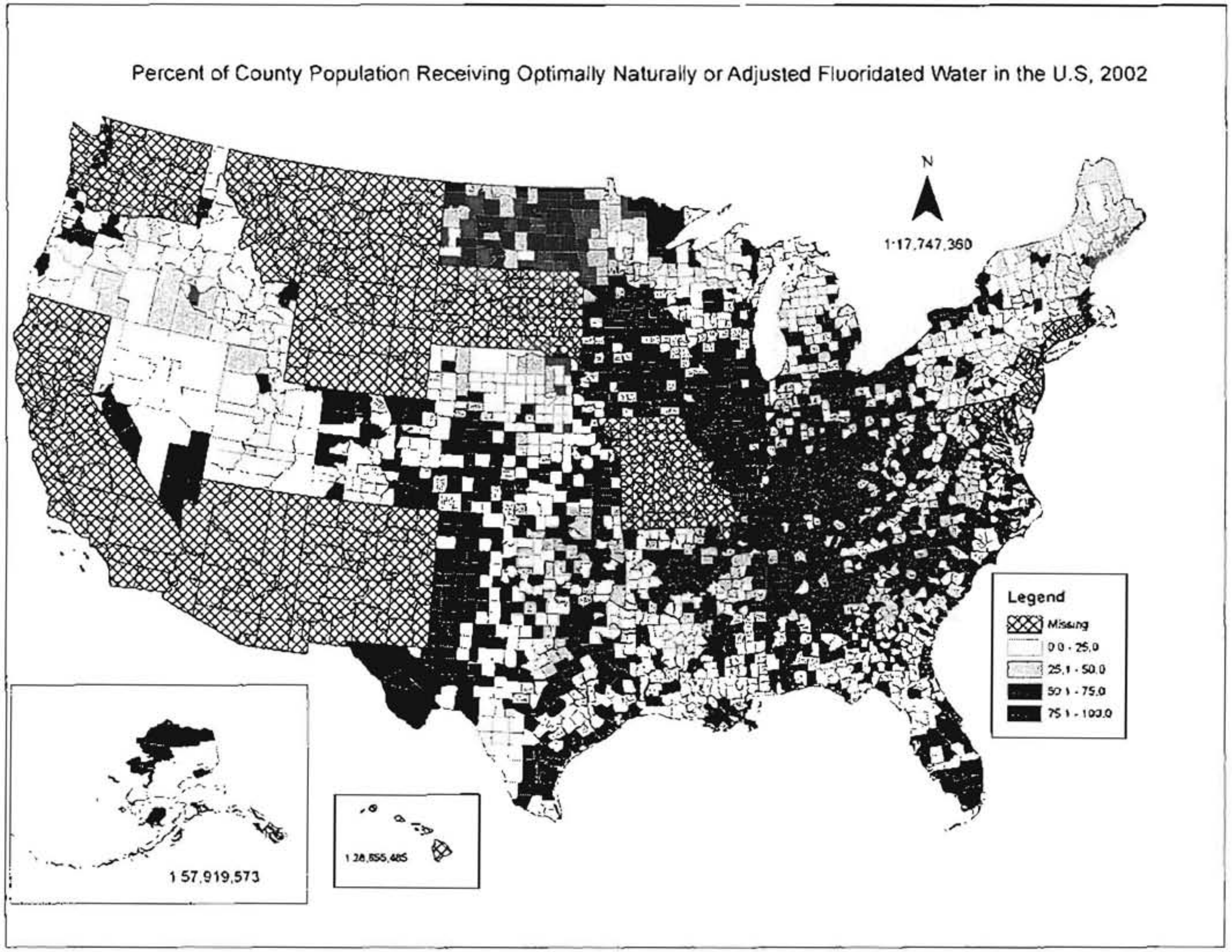


Figure 2-7. County Population Receiving Adjusted or Naturally Fluoridated Water, 2002

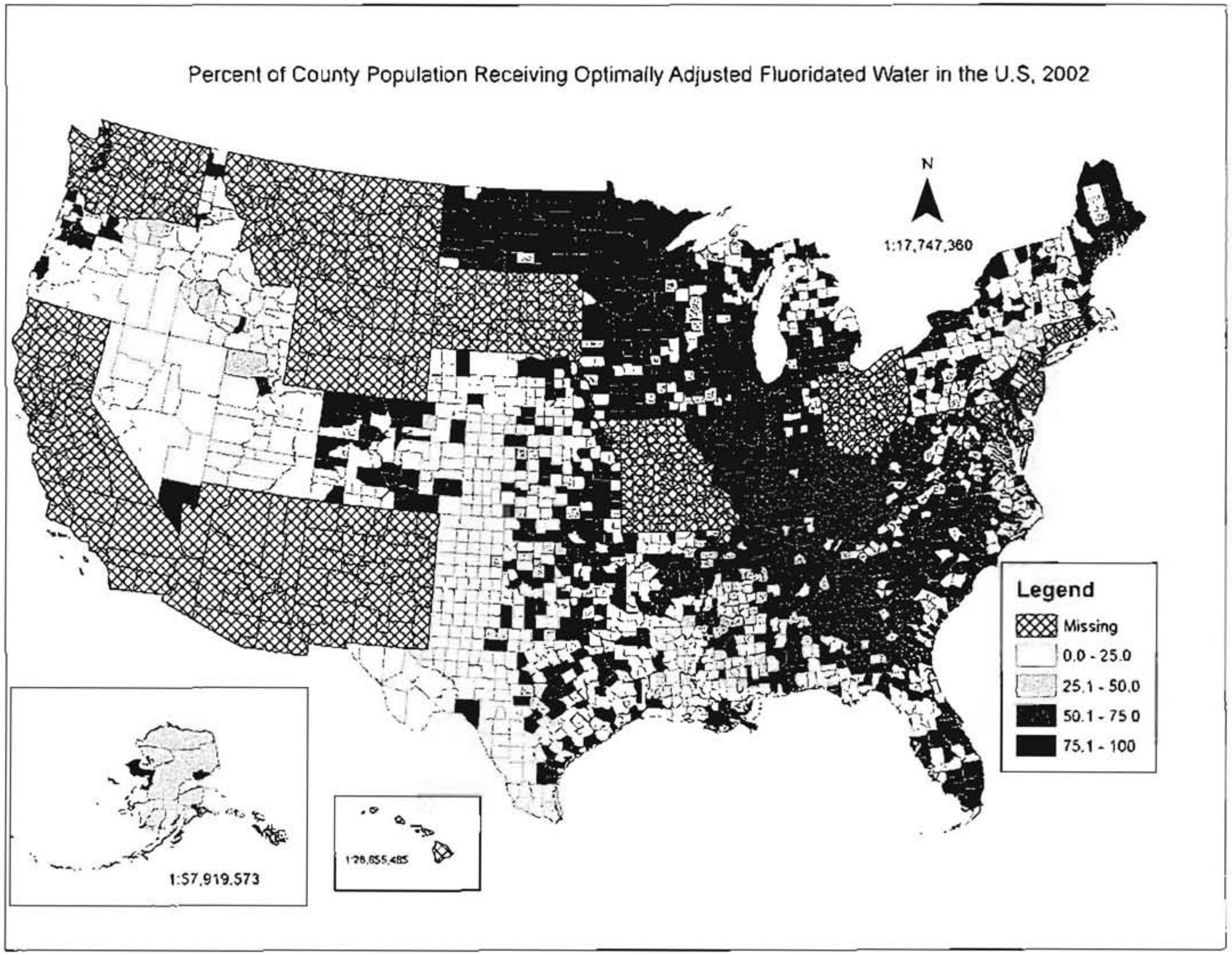


Figure 2-8. County Population Receiving Adjusted Fluoridated Water, 2002

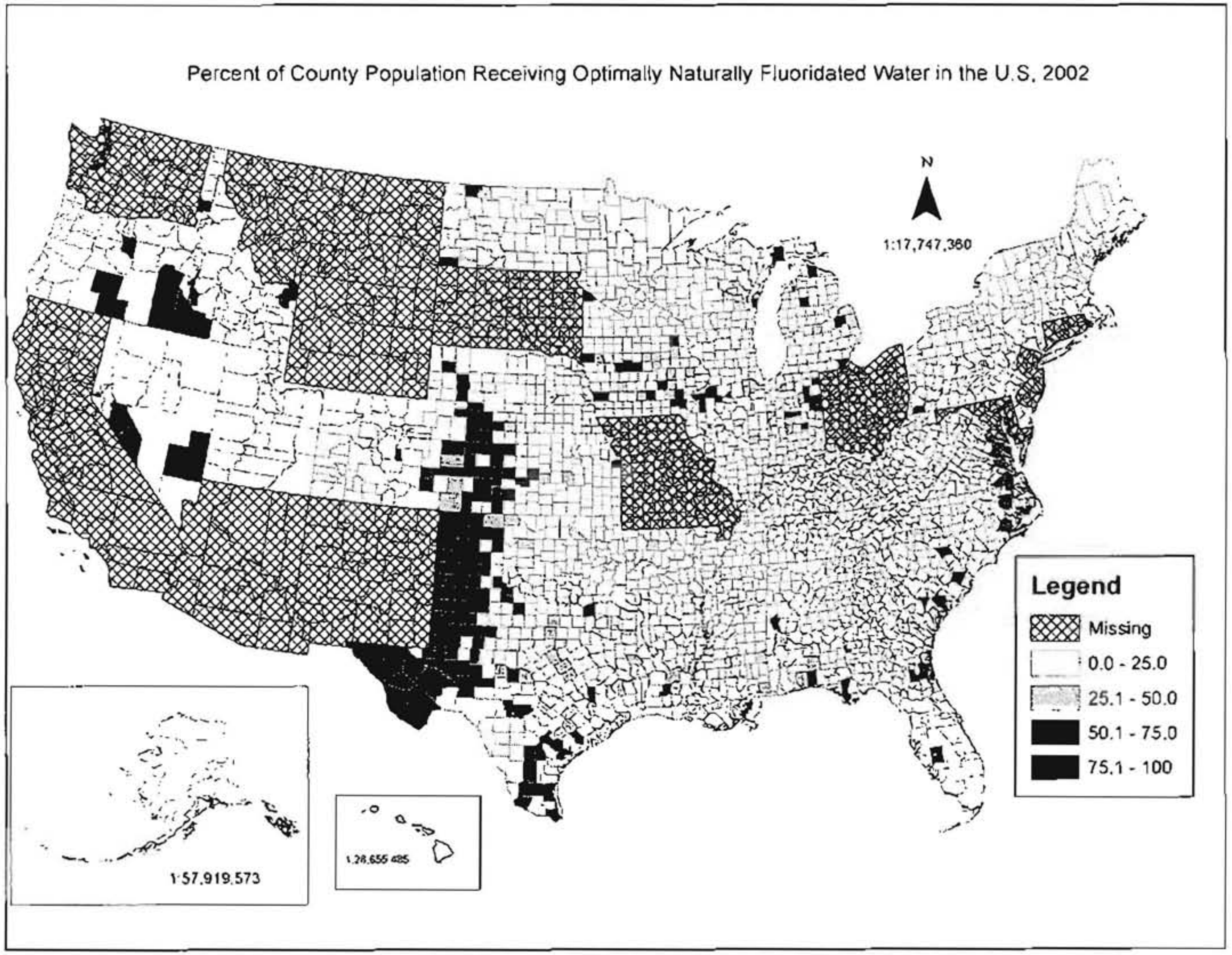


Figure 2-9. County Population Receiving Optimally Naturally Fluoridated Water, 2002

Many communities obtain drinking water by purchasing it from other communities. In most of these cases, the purchasing water system does not have its own fluoridation equipment, so the decision to fluoridate is made by the providing water system. In Illinois, widespread fluoridation was achieved when metropolitan areas like Chicago, which currently provides water to 138 communities, began fluoridation in 1956 (Centers for Disease Control n.d.). Consecutive systems that receive water from large metropolitan water systems account for much of the fluoridation in California. For example, in 2007 the Metropolitan Water District of Southern California (MWD) began providing fluoridated water to 26 water systems it supplies, which currently serve 18 million people (Metropolitan Water District of Southern California 2007).

2.6 The role of government

Another element to be considered in the adoption of fluoridation is the role of government. There are several government entities to be considered. On the federal level, Congress, the Department of Health and Human Services, the Public Health Service (PHS), and CDC have all been important actors. The federal government has largely been motivated by two goals: reducing government expenditures on dental health, and improving dental health in children. The CDC continues to support fluoridation in its public statements, but there has been little federal government-sponsored fluoridation activity in recent years. Currently, CDC provides a total of $4.6 million in funding for oral health programs, including fluoridation, to 16 states (Centers for Disease Control 2008a). States have passed laws regulating fluoridation and have provided funding for fluoridation equipment, training, and personnel. Local government entities such as cities, counties, or water boards usually determine whether or not to fluoridate or whether to conduct a referendum on fluoridation. Local governmental entities also provide some funding for fluoridation.

Lack of state or community support for fluoridation is a barrier to its adoption. The effect of state support for fluoridation can be measured in several ways. Promotion of fluoridation may be seen as an indicator of the state's overall commitment to oral health. States have demonstrated their support of fluoridation through funding, passage of state laws to mandate fluoridation, and through promotion of fluoridation to communities and water system operators.

The presence of a full-time state oral health director within the state health agency structure may be seen as an indicator of each state's commitment to improving oral health. Oral health directors are also among the primary proponents of CWF. State oral health directors constitute the membership of the Association of State and Territorial Dental Directors (ASTDD), a prominent pro-fluoridation professional association (Association of State and Territorial Dental Directors 2008). However, some states have only part-time oral health directors, and several states do not have an oral health director. Table 2-4 provides an overview of the situation.

Table 2-4. Summary of State Dental Director Positions, 1993-2003

Year	1993	2003
Full-time dental director	35	41
Part-time dental director	5	3
No dental director	10	7
Legislative mandate for dental health director position	20	Not available

(Centers for Disease Control 1994; Oral Health America 2003)

A number of states have passed, or attempted to pass, legislation governing CWF. Appendix A lists legislative measures regarding fluoridation that have been passed, and Appendix B lists unsuccessful fluoridation legislation. The lists were compiled from news reports, a published list (Greer 2000), and state oral health web sites. Eleven states currently have statewide laws mandating fluoridation for some or all of the state population. Delaware, Georgia, Illinois, Minnesota, and Nebraska require fluoridation for all community water systems. California, Connecticut, Kentucky, Nevada, Ohio, and South Dakota require fluoridation above a certain population threshold. Maine, Massachusetts, Michigan, New Hampshire, and Utah have passed laws governing the methods through which fluoridation is to be adopted. I categorized the laws as fluoridation mandates or procedural laws.

Many states have recently considered fluoridation legislation, but these measures have generally been unsuccessful. Nevada and Nebraska were the states that most recently passed laws mandating fluoridation, in 1999 and 2008, respectively. In both cases, the mandates only affected communities over a certain population threshold. In Nevada, the law applies to water systems that serve over 100,000 people, which effectively restricted the law's applicability to the largest water systems, which serve Las Vegas and Henderson (Nevada State Oral Health Advisory Committee n.d.). The remainder of the state has very low levels of fluoridation. In Nebraska, communities may opt out of fluoridation through a referendum, so the effect of the law is to mandate a decision, not to actually mandate fluoridation (Crozier 2008). More importantly, even states with fluoridation mandates, like Ohio, still have unfluoridated counties (see Appendix I).

Inclusion of goals related to CWF in a state's oral health plan or an overall public health plan might be an indicator of the state's support for CWF. On the other hand, CWF may simply be included in state plans because of the influence of ASTDD and CDC without there being tangible support in the form of funding or personnel. There is an inherent conflict between states' motivation to promote CWF (mainly to reduce Medicaid costs) and the local decisionmakers' desire to sidestep controversy by avoiding making fluoridation decisions. This tension between state and local officials was mentioned by oral public health officials in New York in describing the difficulty of coordinating efforts between the Bureau of Dental Health and the Bureau of Water Supply and Protection. While the Bureau of Dental Health promotes fluoridation to water systems, the Bureau of Water Supply and Protection and local health departments are responsible for implementing and managing fluoridation operations (Reuther and Veschusio 2008). In other words, fluoridation promoters at the state level may not have sufficient influence over local water systems.

Looking at the issue from another perspective, in some cases a larger jurisdiction has the authority to mandate or prohibit fluoridation, so the fluoridation decision is not within the control of the water system or local community. In Hawai'i, the City and County of Honolulu passed an ordinance prohibiting fluoridation in 2004 (Shapiro 2004). This county measure affected 11 water systems on the island of O'ahu that serve 882,830 people, or 68.8 percent of the state population. In this case, the local water system's control was trumped by the county ordinance. If Honolulu County were fluoridated, the percent of the state population receiving fluoridated water would jump from the current 8.6 percent to 77.4 percent. This effect works the opposite way, too, when states pass fluoridation mandates that do not permit communities to opt out.

2.7 The economics of fluoridation

Fluoridation is enthusiastically promoted by governments and oral health professionals as the best way to improve dental health. Several studies have been published concerning the costs and benefits of initiating fluoridation. A General Accounting Office (GAO) report stated that tooth decay was enormously expensive to the federal government and to states, and it advocated water fluoridation as a cost-effective means of reducing these costs (General Accounting Office 1979). GAO also recommended that Congress should provide funding for communities that wished to initiate fluoridation.

A number of studies have used various methods to estimate potential cost savings to be derived from CWF. The American Dental Association (ADA) cited a cost of $3.35 per tooth to prevent decay, versus $75.84 to place an amalgam filling in a decayed tooth (American Dental Association 2005). One study of fluoridation in Houston calculated the value of cavities prevented by fluoridation to be $51,573 in the first year up to $769,880 in the 20th year following fluoridation (Nelson and Swint 1976). The Public Health Service estimated that $36 in caries treatment could be saved for each dollar spent on fluoridation (General Accounting Office 1979). A recent assessment in Colorado estimated an annual cost savings of $46.6 million if fluoridation were implemented in non-fluoridated communities and a cost-benefit ratio of $21.82 to $135.00 for existing systems (O'Connell, Brunson et al. 2005).

2.7.1 Costs of fluoridation equipment, supplies, and personnel

A study of 44 Florida communities determined the cost per person to install fluoridation equipment to be about $0.45 per person based on the size of the community (Ringelberg, Allen et al. 1992). The Public Health Service in 1999 estimated that fluoridation costs ranged from $0.31 per person in communities with populations greater than 50,000 to $2.12 per person in communities of less than 10,000 ("Achievements in public health, 1900-1999: fluoridation of drinking water to prevent dental caries" 1999). The ADA states that the annual cost of CWF is $0.50 per person, and the annual cost ranges between $0.12 and $5.41 depending on the community size, type of equipment used, type of fluoride chemicals used, and labor costs (American Dental Association 2005).

States have largely been motivated to promote fluoridation in order to reduce Medicaid payments. California's statewide law is clearly an example of this thinking (Boyd 1997). Although many studies have calculated the estimated savings in oral health costs brought about through fluoridation, studies that have documented actual savings in Medicaid or SCHIP payments are lacking. One study of children aged one to five in Louisiana concluded that Medicaid payments for dental care were twice as high in unfluoridated areas (Barsley, Sutherland et al. 1999). The author acknowledged that the study was not generalizable to other age groups, and it did not distinguish between children who had grown up in fluoridated areas from those who had moved into or out of fluoridated communities.

Another line of research has related the success of fluoridation with the availability of funding for equipment and personnel. One study found a correlation between increased adoption of fluoridation and the presence of a full-time coordinator of fluoridation activities (Easley 1990). In contrast, states that had small increases or declines in the number of people on fluoridated water were those that had not received federal or state support for fluoridation programs. Similarly, a decline in funding available for fluoridation programs was observed in several states, including California, in the early 1980s after categorical funding for public health measures was replaced by block grants to states ("Fluoridation suffers under block grant program" 1983).

2.7.2 Sources of funding for fluoridation equipment and personnel

Funding for fluoridation may come from public or private funds, or a combination of sources. It was not possible to systematically compile data on state funding for fluoridation, but anecdotal evidence is available from news reports. Some states provide grants to water systems for fluoridation equipment. California's statewide law mandating fluoridation if funding is available has resulted in the emergence of a number of funding sources. The California Dental Association provides fluoridation grants to cities, as does the Dental Health Foundation, the Alliance Healthcare Foundation, the Sierra Health Foundation, and the California Endowment (Duerksen 1998). The California Endowment allocated $5.5 million for fluoridation of the Metropolitan Water District of Southern California (Kelley 2005). In Washington state, funding for fluoridation projects has been provided by Washington Dental Service Foundation, primarily funded by Washington Dental Service, which is Washington's largest dental insurer (Kawada 2004). The Yakima County Children's Oral Health Coalition offered a grant of $179,000 for startup costs and the first year's operation in Yakima (Ashton 1999).

Federal funding for fluoride promotion has declined since CWF began in the U.S. In the 1970's, the Public Health Service spent less than $200,000 a year on fluoride promotion (General Accounting Office 1979). Today, fluoridation is not a line item in CDC's $11 million annual oral health budget (Centers for Disease Control, National Center for Chronic Disease Prevention and Health Promotion et al.). CDC awards grants to states for fluoridation promotion, among other oral health measures, but no funds are designated specifically for the promotion of CWF. One component of the current research was a survey of state oral health directors, who were asked about the availability of funding for fluoridation initiatives. The survey is discussed in detail in Chapter 4.

2.7.3 Shortages of fluoridation chemicals

Fluoride may be added to water systems in the form of liquid fluorosilicic acid (FSA), dry sodium fluorosilicate, or dry sodium fluoride. Water systems are designed to use particular fluoridation additives and cannot easily switch to dry fluoridation chemicals if their equipment is designed for liquid FSA (American Water Works Association 2007). FSA is produced in the U.S. Half of the supply of sodium fluorosilicate is produced in the U.S., and the remainder originates in Asia. Almost all sodium fluoride is produced in Asia (Centers for Disease Control 2008b). In the past few years, shortages of FSA have occurred. Initially, shortages were regional and affected only a few water systems. However, the deficiency has become more widespread, and prices of fluoridation chemicals have risen significantly. In fact, a few water systems have discontinued fluoridation as a result of shortages or price increases (ActionPA.org 2007). In most cases, the discontinuations have been temporary, but some water systems have elected to cease water fluoridation altogether. For example, the city of Inverness, Florida decided to cease fluoridation as a result of decreasing supply and price increases for fluoride (Shoichet 2006). The shortages are due to several factors, including a decline in the number of producers of fluoridation chemicals and the closure of production facilities. In addition, demand for fluoride for purposes other than treatment of public water supplies has also affected its availability.

2.8 Government data on the fluoridated population of the U.S.

It is important to note how the numbers of people served by CWF are derived. The U.S. Department of Health, Education, and Welfare conducted the first fluoridation census of states in 1956. CDC has been responsible for maintaining data on the fluoridated populations of each state since 1978. Through 1992, data was collected from each state through the National Fluoridation Census. Each state was given a printout of the previous fluoridation census (censuses were conducted in 1980, 1985, and 1992) and asked to update the fluoridation data and population figures based on Census Bureau estimates. One difficulty with this method of estimating population is that water system boundaries do not generally coincide with Census Bureau geography. In addition, some states lack the personnel resources to provide accurate updates (Centers for Disease Control and Prevention Division of Oral Health 2007).

Both CDC and the Environmental Protection Agency (EPA) require the reporting of fluoridation levels, with important differences. The EPA's *Safe Drinking Water Information System* (SDWIS) is a database listing water quality data and violations of water quality regulations for water systems in the U.S. The data in SDWIS is compiled from water quality reports submitted to the EPA by water system administrators as required by the Safe Drinking Water Act. Starting in 2000, the CDC implemented the *Water Fluoridation Reporting System* (WFRS) database to monitor CWF and compile reports on the populations using fluoridated water at the national, state, and county levels. State water fluoridation managers are responsible for updating WFRS (Centers for Disease Control

2007). Each state drinking water program has developed its own method for estimating the population served by each water system in the state. Usually, estimates are based on an assumed number of people per connection, a method that has resulted in overcounting in some cases (Centers for Disease Control and Prevention Division of Oral Health 2007). An examination of data in CDC's *Oral Health Maps* database (Centers for Disease Control and Prevention 2008) shows that in some counties, the fluoridated population reported by the state exceeds the Census population listed. Because state fluoridation managers report fluoridation data to CDC, while water system directors report fluoridation levels to EPA, there are some discrepancies in population figures between MWF and SDWIS. CDC states that it conducts an annual comparison to identify discrepancies between WFRS and SDWIS, but it is left to each state to update the information in each of these systems.

The case of Hawai'i provides an example of conflicting data resulting from deriving fluoridated populations from the number of connections. According to CDC, 8.6 percent of the state population received fluoridated water in 2002 ("Populations receiving optimally fluoridated public drinking water -- United States, 2000" 2002). However, only military bases in Hawai'i are fluoridated (Kanna 2004). The population served by military water systems is calculated using the resident base population plus one third of the base population (U.S. Army Corps of Engineers 1984). According to the *Hawai'i Data Book* (State of Hawaii Department of Business Economic Development and Tourism 2008), the military population of Hawai'i in 2002 was 44,516, or 3.6 percent of the total state population. It seems unlikely that the fluoridated population of Hawai'i could be as high as what has been reported to CDC.

One might expect that the fourteen states that do not list data in MWF would have an alternate means for consumers to look up the amount of fluoride in their drinking water. Table 2-5 provides an overview of the availability of consumer information provided by states about water fluoridation. While some states publish lists of fluoridated communities, consumers in states that do not provide such lists must contact their water systems.

Table 2-5 Consumer Information about Water Fluoridation in Non-MWF States

State	World Wide Web data
Arizona	List of fluoridated water systems last updated in 2004; refers users to CDC, where no additional information is available
California	List of fluoridated water systems dated November 2007
Connecticut	Provides a low-resolution map of fluoridated areas, but no list of water systems
Hawai'i	No information provided
Maryland	No information provided
Missouri	A clickable map of counties links to a list of fluoridated communities in each county
Montana	No information provided
New Jersey	No information provided
New Mexico	No information provided
Ohio	A clickable map of counties links to oral health data including fluoridation for each county
Rhode Island	List of fluoridated and unfluoridated water systems dated November 2007
South Dakota	Statement that communities with population over 500 are fluoridated, but no list of fluoridated or unfluoridated systems
Virginia	No information provided
Washington	List of fluoridated water systems last updated in 2003
Wyoming	No information provided

Compiled from state oral health web sites as of August 2008.

In 2002, CDC issued its first report on the water fluoridation status of each state using WFRS data ("Populations receiving optimally fluoridated public drinking water -- United States, 2000" 2002). The report states that, "Alabama, California, Kansas, Louisiana, Montana, Rhode Island, Texas, and Wyoming had not updated their data," by the time the report was being compiled, so the 1992 data were used for those states. The use of outdated information to report water fluoridation status is apparently a long-standing practice that calls into question the accuracy of CDC figures reporting the percent of the U.S. population drinking fluoridated water.

There are some discrepancies between the data in MWF and the 1985 *Fluoridation Census* (Fluoridation census 1985), which was used for historical population data. For example, the population figures for 2000 are questionable in some instances, indicating zero population growth in communities where population growth can be demonstrated to have occurred between 1985 and the early 2000's. It seems likely that in such cases, the state did not update some or all of their population estimates. In addition, the dates of initiation of fluoridation sometimes do not agree. While it is understandable that not all of the water systems listed in MWF would be reflected in the *Fluoridation Census*, which only lists communities with fluoridated water, there are several instances where communities that were fluoridated in 1985 according to the current MWF are not listed on the Fluoridation Census or vice-versa. Furthermore, a few communities that are listed as having optimally naturally fluoridated water in one source indicate that fluoride is adjusted in the other, but there is no indication that these communities changed water sources between 1985 and 2000. It is likely that the data for some states is much more accurate than for others. These discrepancies are mentioned here because, without a detailed analysis of the accuracy of these data sources, it is difficult to estimate their extent or to know how inaccuracies in the CDC's fluoridation data might affect the present research. For lack of better data, I have used the population and fluoridation figures provided by CDC in its databases.

In 2003, the Environmental Protection Agency (EPA) issued a report that tested the methodology for estimating fluoride occurrence (Environmental Protection Agency Office of Ground Water and Drinking Water 2003). In a comparison between the *Fluoridation Census 1992*, the unpublished *Fluoridation Census 2000*, and a cross-section of data from 16 states, the EPA found a large discrepancy in both the number of fluoridated systems and the estimated population served by CWF. However, the EPA explained the discrepancy by pointing out that data for Chicago was missing from the Illinois data, and that small water systems were represented better in the cross-section data. Nevertheless, the study further demonstrates the need to improve methods of estimating the fluoridated population of the U.S.

2.9 Research questions

Frazier (1980) suggested that the fluoridation controversy be conceptualized as a process operating at multiple scales. Fluoridation was initially promoted at the national level by the federal government. State governments, through lawmaking and funding, have had varying degrees of influence on CWF. Counties, water boards, utility boards, and health boards covering larger or smaller geographic areas are often involved in fluoridation decisions.

Municipal governments and interest groups are often the initiators of pro- or anti-fluoridation efforts. Finally, individuals' perceptions of the nature of water fluoridation have had an immeasurable impact on the growth of fluoridation as demonstrated by voting in fluoridation decisions.

Given the variety of entities and groups involved and the availability of data, studying the process of the adoption of water fluoridation necessitates analysis at multiple geographical scales. The quantitative portion of this study used data at the national, state, county, and water system levels in its analysis of several variables that may have influenced the adoption of water fluoridation. Variables related to the need for fluoridation, barriers to the adoption of fluoridation, and government structures that support fluoridation were analyzed. In the survey of state dental directors, questions were formulated to gain an understanding of state support for oral public health and CWF.

2.9.1 Measures of need: caries, Medicaid/SCHIP eligibility, and poverty

As discussed earlier, it is difficult to assess the relationship between the prevalence of caries and CWF. Lack of consistent caries data across states has led me to conclude that analysis of caries at the state level would not be reliable. Caries data is available for Ohio counties, so Ohio is the only state examined in this thesis. The question to be addressed by the present study is:

- Is fluoridation more prevalent in areas where the incidence of caries is high?

A question that arises from pro-fluoridation arguments is: Does fluoridation actually reach children who lack access to dental care? As discussed in Section 2.3.2, Medicaid/SCHIP eligibility is an indicator of lack of access to affordable dental care. Data is available for all 50 states and counties in Ohio. The question to be addressed is:

- Is fluoridation more prevalent in areas with higher percentages of children eligible for Medicaid/SCHIP?

Fluoridation has been promoted as a low-cost means of improving dental health. Because poverty data is available at the county level for the entire country, it is possible to test whether counties with a higher proportion of the population below the federal poverty level are more likely to have higher levels of fluoridated water as measured by fluoridation category. The key question is:

- Is fluoridation more prevalent in areas with more people in poverty?

2.9.2 Barriers to adoption of CWF: population size, rurality, and decentralized decision-making

As described earlier, a number of the communities that have not adopted fluoridation are small water systems where the per-capita cost of fluoridation is higher. Rural counties are less likely to have access to public water supplies that could be fluoridated. Two questions related to population size and rurality will be addressed:

- Are smaller water systems less likely to be fluoridated?
- Is fluoridation is more prevalent in urban counties than in rural counties?

The present study will attempt to confirm the results of previous research by testing whether communities where the authority for adopting fluoridation is centralized were more likely to adopt fluoridation than communities in which authority is shared by a greater number of stakeholders. The research question is:

- Is there a relationship between the results of fluoridation decisions and the type of authority used?

2.9.3 State support

As discussed in Section 2.6, state support of fluoridation can be measured in a variety of ways. This study will examine the relationship between state support and fluoridation levels using state-level data on the presence of a full-time dental director, the existence of a statewide law mandating fluoridation, and the inclusion of fluoridation in an overall oral health plan. The survey of state dental directors also addresses state support of oral health and fluoridation. Research questions about state support are:

- Does state administrative structure support affect the adoption of fluoridation?
- Has state support of fluoridation changed over time?
- How do states promote CWF?
- What do dental directors perceive as the main barriers to the adoption of CWF?

Table 2-6 lists the variables to be quantitatively analyzed:

Table 2-6. Independent and Dependent Variables

Independent Variables	**Level**	**Data Available**
Prevalence of dental caries	Interval/ratio	County
Percentage of school-aged children eligible for Medicare/SCHIP	Interval/ratio	State, County
Poverty status	Nominal	State, County
Population size	Interval/ratio	Water system
Urbanization	Nominal	County
Locus of decision-making authority	Nominal	Water system
State support for fluoridation	Nominal	State
Dependent Variable		
Fluoridation status	Nominal	Water system
Fluoridation category	Ordinal	State, county
Fluoridation prevalence	Interval/ratio	State, county

3. QUANTITATIVE ANALYSES OF STATES AND COUNTIES

The fluoridation status of individual water systems was obtained from the *My Water's Fluoride* database (Centers for Disease Control n.d.). Fluoridation data for counties and states is from the *Oral Health Maps* database (Centers for Disease Control and Prevention 2008).

3.1 Measures of need

Multiple regression analysis was conducted to determine the relative strengths of these independent variables as predictors of fluoridation levels: the percent of counties without a dentist, Medicaid/SCHIP eligibility, and poverty. Medicaid/SCHIP data for 2003 was obtained from *Child Health USA* (Maternal and Child Health Bureau 2005). Percent of counties without a dentist was compiled from synopses of state oral health programs (Centers for Disease Control National Center for Chronic Disease Prevention and Health Promotion 2005). The *County and City Data Book 2007* (U.S. Census Bureau 2007), table B4, lists percent of persons in poverty in each state and county for 2004. None of the independent variables were found to be significant predictors of the prevalence of fluoridation (results are in Table 3-1; $R = .183$ and $R^2 = .033$).

Table 3-1. Multiple Regression of State Need-related Variables

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	54.541	19.311		2.824	.008
	NoDentist	-.252	.578	-.073	-.435	.666
	Medicaid	-.486	.748	-.145	-.651	.520
	Poverty	2.131	2.016	.237	1.057	.298

3.2 Barriers to fluoridation: population size and rurality

3.2.1 Population size

In this study, 6,232 water systems serving 3,300 or more people were selected for analysis by querying the Safe Drinking Water Information System (SDWIS) of the EPA (Environmental Protection Agency). SDWIS is a database listing water quality data for water systems in the U.S. and violations of water quality regulations. The data in SDWIS is compiled from water quality reports submitted to the EPA as required by the Safe Drinking Water Act. In SDWIS, communities are categorized by size: medium (3,301 to 10,000), large (10,001 to 100,000), and very large (over 100,000). Communities with "small" or "very small" populations (less than 3,300) were excluded from this study because those systems usually include schools and other institutions, mobile home parks, and other small developments that do not have policymaking power analogous to city councils, health boards, or municipal executives. The District of Columbia and water systems on military bases were excluded from this study because they are under the jurisdiction of the federal government. Water systems exclusively serving institutions such as prisons, state hospitals, or schools were excluded because many of the variables do not apply to these populations and they are under state rather than local control.

Table 3-2 summarizes the fluoridation statuses of 6,232 water systems with populations over 3,300 that were analyzed.

Table 3-2. Summary of Fluoridation Status of Water Systems Serving Populations over 3,300

		Water System Size			
		Medium	Large	Very Large	Total
Current_Status	Adjusted Fluoride	1908	1624	175	3707
	Natural Fluoride	418	196	19	633
	Non-fluoridated	1374	488	30	1892
	Total	3700	2308	224	6232

Logistic regression was employed because the dependent variable, fluoridation status, is categorical. The analysis confirms the positive relationship between population size and fluoridation status for communities with adjusted fluoride and without fluoride. Population size was not significantly associated with natural fluoridation. Table 3-3 summarizes the results (Cox & Snell pseudo-$R^2 = .041$).

Table 3-3. Regression Analysis of Population Size and Fluoridation Status

Current_Status[a]		B	Std. Error	df	Sig.	Exp(B)
Adjusted Fluoride	Intercept	1.764	.198	1	.000	
	[Medium]	-1.435	.201	1	.000	.238
	[Large]	-.561	.204	1	.006	.570
	[Very Large]	0^b	.	0	.	.
Natural Fluoride	Intercept	-.457	.293	1	.119	
	[Medium]	-.733	.298	1	.014	.480
	[Large]	-.455	.305	1	.136	.634
	[Very Large]	0^b	.	0	.	.
a. The reference category is: Non-fluoridated.						

3.2.2 Rurality

U.S. counties for which fluoridation data was available were examined to determine the relationship between rurality and fluoridation status. The classification of counties as rural, or nonmetro, was obtained from the Economic Research Service (ERS) of the U.S. Department of Agriculture. The ERS uses the Office of Management and Budget definitions of metro and nonmetro areas: "metro areas [are] (1) central counties with one or more urbanized areas, and (2) outlying counties that are economically tied to the core counties as measured by work commuting….Nonmetro counties are outside the boundaries of metro areas…" (Economic Research Service 2007). Table 3-4 summarizes the categorization of 2,639 counties for which fluoridation data was available as nonmetro (0) or metro (1). About half of the counties studied were classified as nonmetro (rural). In contrast, 65.3 percent of all counties in the U.S. are classified as nonmetro. For convenience, Table 3-4 summarizes the distribution of counties across the CDC fluoridation categories.

Table 3-4. Summary of Urban/Rural Category and Fluoridation Category

		Metro_code		
		0	1	Total
Fluoridation Category	1	549	195	744
	2	350	140	490
	3	397	182	579
	4	441	385	826
	Total	1737	902	2639

Regression analysis on the 2,639 counties indicates that there is a statistically significant positive relationship between metro code and fluoridation category. Counties categorized as metro are more likely to have higher levels of fluoridation than non-metro counties. Table 3-5 presents the results. However, the values of R (.065) and R^2 (.004) indicate that the predictive power of this model is very low.

Table 3-5. Regression Analysis of CDC Fluoridation Category and Metro/Nonmetro Category

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	47.014	3.688		12.748	.000
	Metro_code	21.068	6.308	.065	3.340	.001

3.3 State support for fluoridation

State activities in the promotion of CWF include providing funding for fluoridation equipment, supplies, and/or personnel; including CWF in state public health plans; and the passage of statewide laws mandating CWF. Data from the survey conducted for this study, published accounts of state fluoridation activities, state oral health division annual reports, Association of State and Territorial Dental Directors published summaries (Association of State and Territorial Dental Directors 2008), and information on state oral health division web sites was used. Appendices A and G contain the data tables.

Table 3-6 illustrates the results of a multiple regression analysis of state support for fluoridation using three variables: presence or absence of a full-time state dental director, statewide laws regarding fluoridation, and fluoridation as part of an overall health plan or oral health plan. None of these variables were found to be statistically significant predictors of fluoridation levels, and the predictive power of the model was very low (R = .162 and R^2 = .026).

Table 3-6. Summary of Regression Analysis of State Fluoridation Support

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	63.343	12.466		5.081	.000
	PLAN	7.603	8.628	.151	.881	.384
	OHDIR	1.056	11.801	.015	.089	.929
	LAW	-3.392	6.063	-.096	-.560	.579
a. Dependent Variable: FlPopAll						

3.4 Decision-making authority

Data on fluoridation decisions made between 1980 and 2007 in 249 communities was collected by scouring the LexisNexis Academic database (LexisNexis 2008), the PubMed database (National Library of Medicine 2008), and the Fluoride Action Network web site (Fluoride Action Network 2008) for news and journal articles about fluoridation decisions. I classified the type of authority in each decision using Rogers' (1995) typology as optional, collective, or authority. Referenda were classified as *optional*. *Collective* authority refers to bodies such as water boards, health boards, village boards, and city or town councils. The *authority* classification covers decisions made by an executive such as a water system administrator, mayor, or city manager. Because it is generally not possible to readily access data sources such as city council meeting minutes beyond the past few years, it was not possible to include communities that had declined to consider fluoridation between 1980 and 2007 in the analysis.

Table 3-7 summarizes the distribution of decision-making authority and results of votes.

Table 3-7. Decision-making Authority in Fluoridation Votes, 1981-2008

		Authority			
		Central Authority	Collective	Optional	Total
Result1	N	4	48	66	118
	Y	1	72	58	131
	Total	5	120	124	249

Regression analysis of 249 fluoridation decisions made between 1981 and 2008 indicated that the type of decision-making authority is not a significant predictor of the outcome (Table 3-8 presents the results; Cox & Snell pseudo-R^2 = .026).

Table 3-8. Regression Analysis of Fluoridation Decisions

Result1[a]		B	Std. Error	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
							Lower Bound	Upper Bound
N	Intercept	.129	.180	1	.473			
	[Central]	1.257	1.132	1	.267	3.515	.382	32.350
	[Collective]	-.535	.259	1	.039	.586	.353	.973
	[Optional]	0	.	0	.	.	.	.

a. The reference category is: Y.

3.5 Ohio counties

Analysis of the entire U.S. at the county level would be preferable for caries prevalence and Medicaid eligibility. However, the data for these variables was only available for Ohio counties. In Ohio, fluoridation is mandated in communities over 5,000 population, but cities were allowed to opt out within 240 days of the law's enaction by conducting a referendum (Ohio Department of Health 2003). Seven counties are in the lowest CDC fluoridation category (0-25 percent) and two counties (Holmes and Morgan) have no fluoridated communities. Data on the percent of Ohio third-graders in each county with untreated decay who were examined in 2004-2005 is from the Ohio Oral Health Surveillance System (OOHSS) (Ohio Department of Health 2007b). Figures for the percent of persons receiving fluoridated water, the percent of children eligible for Medicaid, and the percent of people living in poverty are also from OOHSS.

Metro/nonmetro codes are from ERS (Economic Research Service 2007). The data for the 88 counties in Ohio is reproduced in Appendix I.

Multiple regression analysis (Table 3-9) did not indicate that any of these variables had a significant effect on fluoridation. Furthermore, the low values of R (.208) and R^2 (.043) show that this model does not have significant predictive power for fluoridation levels.

Table 3-9. Regression Analysis of Need-Related Variables

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	63.860	11.693		5.461	.000
	Medicaid Eligibility	.152	.506	.067	.299	.765
	Metro code	10.777	6.317	.191	1.706	.092
	Percent of Persons in Poverty	.646	1.898	.077	.340	.735
	Third Grade Caries	-.136	.343	-.054	-.396	.693

4. SURVEY OF STATE DENTAL DIRECTORS

One of the aims of this study, in line with Kodras' (1988) research on areal variations in the adoption of welfare programs, was to develop an understanding of how states promote CWF. Public health advocacy was also identified by Nash (2003) as a significant factor in the adoption of fluoridation in two Pennsylvania cities. I mailed a survey to the dental director (or equivalent) in each state to gather data on state fluoridation activities. The survey questions were formulated to obtain information about the relative importance of CWF in each state, the extent to which the states support CWF, funding available for CWF, and perceived barriers to the adoption of CWF. The survey instrument is reproduced in Appendix D. Twelve responses were received, a 24 percent response rate.

4.1 Full-time dental director

The first question asked the number of years for which a position for a full-time dental director has existed. The purpose of the question was to gain an understanding of the consistency of state support for public health dentistry over time. The mean was 43.3 years and the median was 51.6 years. In three states, a position for a full-time dental director had existed for six years or less (Table 4-1 shows the responses). Because four respondents requested that their responses be kept confidential, I assigned numbers to identify them.

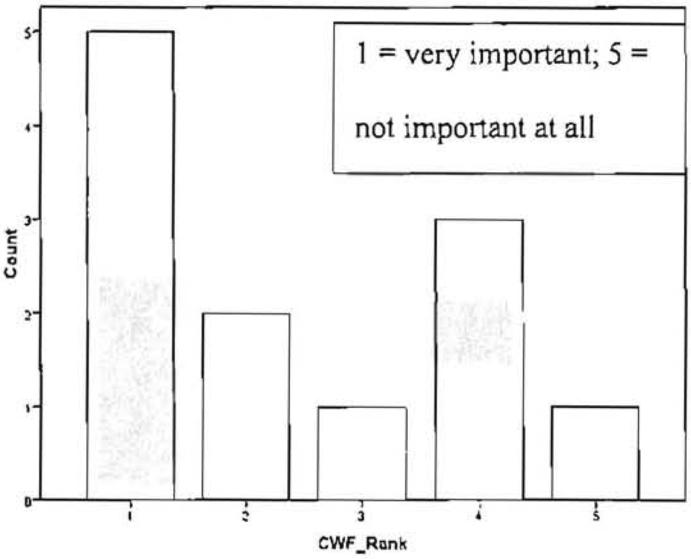
Table 4-1. Position for Full-Time Dental Director

State	Position for Full-Time Dental Director (years)
Respondent 1	6
Respondent 2	38
Respondent 3	73
Respondent 4	4
Respondent 5	70
Respondent 6	60
Respondent 7	62
Respondent 8	79
Respondent 9	70
Respondent 10	3
Respondent 11	12
Respondent 12	Did not answer

4.2 Importance of CWF

Rank of importance of CWF had a mean of 2.42 on a scale of one to five, with one being the highest ranking. Figure 4-1 summarizes the directors' rankings.

Figure 4-1. Ranking of Current Importance of CWF



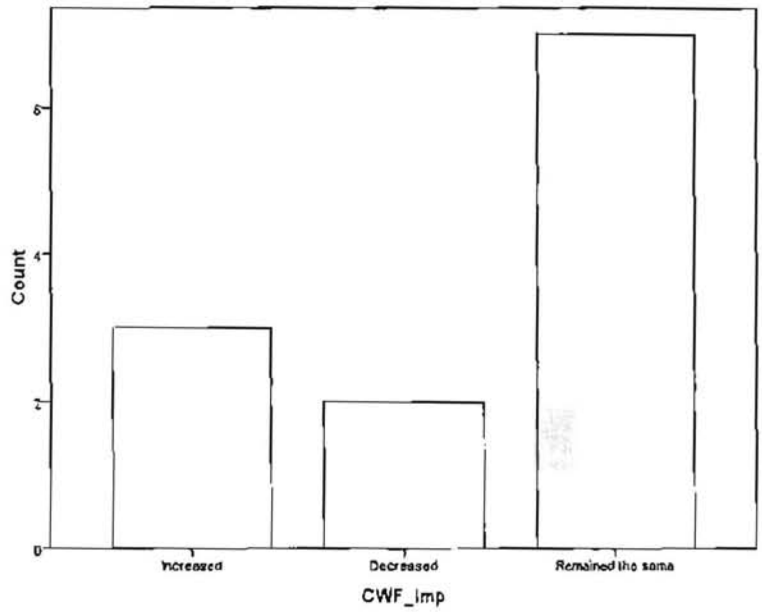
4.3 Inclusion of CWF in public/oral health plan

Respondents were asked about the inclusion of CWF in their state's public health plan or oral health plan. All of the respondents indicated that CWF was included in either an oral health plan or a public health plan. Three-fourths of respondents stated that CWF was included in their state oral health plans, and one-fourth had a goal related to CWF in an overall public health plan.

4.4 Change in importance of CWF over the past 25 years

Figure 4-2 summarizes dental directors' responses regarding whether CWF has become more or less important or has remained the same over the past quarter-century.

Figure 4-2. State Dental Directors' Perception of Change in Importance of CWF



4.5 Promotional efforts

Table 4-2 summarizes survey responses about methods used in each state to promote CWF. A variety of responses were elicited, falling into three general categories: promotion of CWF to water systems, advocacy, and education and research activities.

Table 4-2. Summary of Methods Used by Survey Respondents to Promote CWF

Methods Used to Promote Fluoridation	Number of Mentions
Promotion to water systems	
Water operator training on fluoridation	3
Courtesy visits to water plants	1
Water System Fluoridation Awards	1
Promotion to water systems	1
Cooperation with other state agencies on monitoring and enforcement	2
Advocacy	
Support fluoridation in community debates	2
Training community advocates	1
Participation in coalition to support CWF	2
Conducting large-scale studies of the effectiveness of CWF	1
Promotion of state laws mandating fluoridation	3
Education and Research Activities	
Information placed on oral health department web site	2
Publication of white papers, journal articles, etc.	2
Technical assistance to communities considering CWF	2
Production of educational materials	1

Note: Multiple responses were permitted.

4.6 Availability of state funding for fluoridation promotion, equipment, and/or personnel

Dental directors of ten states reported that there was no state funding available for CWF. Only two indicated that some state funding was available.

4.7 Availability of non-state funding for CWF

Nine of the respondents reported a variety of federal and other funding sources for CWF, although few were able to indicate the amount of funding. Table 4-3 provides a summary.

Table 4-3. Summary of Non-State Funding Available for CWF

Funding source	Number of mentions	Amount
Centers for Disease Control	3	Not provided
United Methodist Health Ministry Fund	1	Not provided
Local improvement grants	1	Not provided
Unspecified private funds	1	Not provided
Preventive Health and Health Services block grants	1	$10,000
Maternal and Child Health Bureau block grant	1	$20,000
Health Resources and Services Administration State Oral Health Collaborative Systems grant	1	$10,000
Water system fees collected	1	Not provided

Note: Multiple responses were permitted.

4.8 Estimate of the state funds available for CWF promotion

No responses were received to a question about how much state funding was available for the promotion of CWF.

4.9 Impediments to increasing the number of communities served by CWF

Table 4-4 summarizes responses to a question asking about barriers to adoption of CWF. Community opposition was mentioned most frequently.

Table 4-4. Perceived Barriers to Adoption of CWF

Impediment	Number of mentions
Community opposition to CWF/efforts of anti-fluoridation groups	5
Community apathy or lack of knowledge of the benefits of fluoridation	3
Lack of support from elected officials	2
Lack of certified water system operators trained to administer fluoridation	1

Note: Multiple responses were permitted.

The survey results and their implications are discussed further in Chapter 5.

5. DISCUSSION

The purpose of this study was to examine the geographic distribution of CWF in the United States and to contribute to the understanding of the dynamics of the adoption of CWF.

5.1 The geographic distribution of CWF

Mapping at the county level has proven to be a very useful tool to elucidate the geographic distribution of adjusted and natural fluoridation at the state and county level. It appears that states in the Midwest and mid-Atlantic had higher levels of fluoridation than those in other parts of the country, almost all due to CWF rather than natural fluoridation. There is a well-defined band of counties that are optimally naturally fluoridated, running from Nebraska through Kansas, Oklahoma, Texas, Colorado, and probably New Mexico (this could be confirmed if county data for New Mexico were available).

CDC provides mapping at the county level through its *Oral Health Maps* database (Centers for Disease Control and Prevention 2008). However, the interface only allows the display of counties in one state at a time, so national patterns are difficult to discern. Mapping the entire U.S. at the county level more clearly demonstrates that the distribution of fluoridation is not uniform across many states. In some states, especially Nevada and Utah, urban areas in one or two counties account for most of the fluoridation. If one were to map fluoridation at the water system level, it is likely that uneven distribution of CWF across counties would also be evident.

5.2 The need for community water fluoridation

This study looked at several measures of need, as perceived by supporters, to explain geographic variation in the adoption of CWF. The results indicated that the need-related variables were not predictors of fluoridation levels. This supports Kodras' contention that public policies are often implemented where they are easiest to implement, not where they are most needed. My research did not confirm Feiock and West's (1993) research suggesting that need was predictive of policy adoption.

Success in the adoption of fluoridation has been measured by increases in the population served by fluoridated water. This emphasis on meeting population thresholds has diverted attention from the underlying purpose of fluoridation: the prevention of dental caries. It proved difficult to draw any conclusions about the relationship between the geographic distribution of CWF and caries prevalence due to the lack of data on caries incidence, inconsistencies in how data was collected, and the need to separate the effect of CWF from other sources of fluoride. Even the analysis of Ohio counties did not show a clear relationship. What stands out, however, is that caries remains a major oral health problem despite the fact that almost 70 percent of the U.S. population on public water supplies receives fluoridated water.

States and counties with more people in poverty were no more likely to receive fluoridated water than more affluent areas. Medicaid/SCHIP eligibility was not associated with fluoridation levels in states and Ohio counties, either. This finding also supports my contention that need factors alone do not account for variations in the distribution of fluoridation. Case studies of fluoridation efforts at the water system level would help to clarify whether need as perceived by the community has been a factor in fluoridation decisions.

5.3 Barriers to adoption

CWF has been promoted as a "as a high-benefit, low-cost preventive method that benefit[s] old and young, rich and poor alike" (United States Department of Health and Human Services 2000). However, most fluoridation has been achieved by fluoridating urban areas, and CWF often does not reach rural areas, either because of cost or because these areas are not on public water supplies. The results of this study confirmed that urbanized areas and larger communities were more likely to be fluoridated, suggesting that small population size and rurality are barriers to the adoption of water fluoridation. This is consistent with Wong's (1978) research indicating that population size is a predictor of fluoridation status. Given the number of states whose fluoridation mandates have exempted communities under a certain population threshold, it seems likely that states have been more motivated to achieve CDC benchmarks rather than to ensure that CWF is available to the entire state population on public water supplies.

The analysis of fluoridation decisions made since 1980 showed that most decisions were made by groups such as city councils or were voted upon in referenda. In fact, only five of the 249 decisions analyzed were made by a central authority. Centralized decision-making, which had previously been demonstrated to result in more pro-fluoridation decisions (Crain and Rosenthal 1967; Frazier 1980), was little used in the cases studied. There was not a difference between collective authority and referenda in predicting the outcomes of fluoridation decisions. Because the cases were not a random sample of fluoridation decisions, one must be cautious in interpreting the results. State laws regarding decision-making authority for adoption of fluoridation may be operative in some cases.

The responses of the dental directors indicated that there was little state funding and a small amount of public funding available for fluoridation. The respondents did not mention lack of financial resources as a problem, and in fact nine respondents indicated that although state funding was not available, other sources were available. They perceived the greatest barriers to be opposition groups and public apathy.

5.4 Government influence in the adoption of CWF

The analysis of variables related to state support of CWF did not confirm Feiock and West's (1993) conclusion that state influence on communities is significant in the adoption of public policy innovations. It is likely that state influence varies depending on the nature of the policy being promoted. State support for CWF has increased or remained the same in most states, according to survey respondents. Although states give nominal support to fluoridation, tangible evidence of support is frequently lacking. Mentioning CWF in a state oral health plan does not equate to support in the form of fluoridation grants or personnel.

Furthermore, legislators and executives may not be supportive of fluoridation in spite of goals in the state's oral health plan.

The presence of a full-time state dental director was not associated with higher levels of fluoridation. However, as the survey of state dental directors demonstrated, some states have had full-time dental directors for relatively short periods. The survey results showed that state oral health officials have taken a variety of approaches to the promotion of CWF. Education and research activities accounted for very little of these efforts, however. Three dental directors surveyed indicated that they supported CWF by promoting statewide fluoridation mandates, although the nature of their involvement in these campaigns was not explained.

Judging from my reading of state oral health plans, promotion of CWF is one of many responsibilities handled by state oral health directors, and the resources they devote to it are probably very limited. From my survey of the literature, I concluded that Tennessee is the only state that has made noticeable efforts to collect data for the purpose of increasing the adoption of water fluoridation. As described in Chapter 2, many states appear to lack the resources to collect and report oral health or fluoridation data.

Two directors mentioned in their survey responses that they participate in statewide coalitions to promote CWF. Previous research has suggested that interest group activities are among the most important determinants of the outcomes of fluoridation decisions

(Frankel and Allukian 1973; Frazier 1980), so it is surprising that coalition building was not mentioned by more of the respondents.

5.5 Conclusions and recommendations for further research

Aside from population size and rurality, this study did not conclusively identify reasons for geographic variation in the distribution of CWF. The low R^2 values in all of the analyses suggest that there are a variety of explanations for the prevalence of CWF in each state and county. Because so many variables may contribute to the differences between states, case studies of the history of fluoridation efforts and the process of fluoridation in each state would be enormously helpful in uncovering additional data that may explain variation in CWF. For example, the role that funding has played over time and the different sources of funding for fluoridation activities need to be understood. It would also be helpful to investigate how effective interest groups have been in increasing adoption of CWF and whether they operate mostly at the state level or whether they are active in individual communities.

Analysis of the relationships between nested hierarchies of government authorities could contribute to understanding of geographic variation in CWF, as recommended by Kodras (1982). One variable that could be systematically examined is the geographic scale of fluoridation decisions. In other words, to what extent does county or state control affect the adoption of CWF at the water system level? I have pointed out a pair of examples that illustrate how state or county legislation affects local control. First, in Hawai'i, which has no incorporated municipalities, both the state and counties have the authority to pass fluoridation legislation. In Nevada, state legislation was passed specifically to mandate fluoridation in one municipality (Las Vegas). In addition, the survey of state dental directors suggested that education and training for water system operators would increase fluoridation. My research did not uncover any studies related to the promotion of fluoridation to water system operators or investigations of water system operators' attitudes toward CWF. Understanding the views of authorities at the water system level could help to explain why smaller water systems are less likely to be fluoridated.

CDC's emphasis on state fluoridation levels in its literature masks the uneven distribution of CWF within states. CDC decided that the best way to benchmark the adoption of CWF was to select a target of 75 percent of the state population on public water supplies by 2010 (U.S. Department of Health and Human Services 2000). How this particular goal was established has not been explained. It would make sense to develop additional fluoridation goals for counties, dental HPSAs, or other state subdivisions as well.

My review of issues surrounding the adoption of fluoridation suggests additional explanatory characteristics. First, water system size, both in terms of population served and geographic extent, is an important variable that may explain some of the differences between states. For example, while New Jersey was reported to have many small water systems, some of the systems in California are enormous. Second, some communities obtain water from multiple sources, and many water systems (e.g., Chicago) serve numerous communities. The effects of communities' changing water sources or purchasing water from large fluoridated cities may be significant in some states. Third, sizeable portions of the populations of some states are not on public water supplies. These characteristics need to be quantified and their impact on state fluoridation levels needs to be determined.

This thesis has examined the complex process of fluoridation using three distinct approaches that have all contributed to knowledge about the distribution and growth of CWF in the U.S. It is my hope that states will increase our understanding of state and local conditions related to oral health and fluoridation by following the examples of Tennessee and Ohio to improve their data collection and reporting. CDC should continue to encourage and provide financial support for these efforts.

APPENDIX A. STATE LAWS REGARDING FLUORIDATION

State	Date Law Enacted	Summary of Law	Category
Alabama	None		N/A
Alaska	None		N/A
Arizona	None		N/A
Arkansas	None		N/A
California	1995	Fluoridation required in communities over 10,000 if funding available	Mandate
Colorado	None		N/A
Connecticut	1965	Requires fluoridation of water supplies in communities over 20,000	Mandate
Delaware	1968	Authorized the state board of health to order fluoridation and allowed fluoridation referenda	Procedural
Delaware	1998	Requires all municipalities to adjust their fluoride to optimal levels	Mandate
Florida	None		N/A
Georgia	1983	All potable water supplies must be fluoridated	Mandate
Hawai'i	None		N/A
Idaho	None		N/A
Illinois	1967	Requires all community water systems to adjust their fluoride to optimal levels	Mandate
Indiana	None		N/A
Iowa	None		N/A
Kansas	None		N/A
Kentucky	1994	Fluoridation mandatory in communities over 1,500 population	Mandate
Louisiana	None		N/A
Maine	1983	Requires referendum to adopt fluoridation	Procedural
Maryland	None		N/A
Massachussetts	1968	Revoked mandatory fluoridation referenda	Procedural
Michigan	1968	Required all communities to take action on fluoridation within five	Procedural

State	Date Law Enacted	Summary of Law	Category
		years	
Minnesota	1967	Requires fluoridation of all public water supplies	Mandate
Mississippi	None		N/A
Missouri	None		N/A
Montana	None		N/A
Nebraska	1973	Fluoridation required unless prohibited by municipality	Mandate
Nebraska	2008	Requires fluoridation or a referendum in cities over 1,000 population	Mandate
Nevada	1999	Fluoridation required in communities over 100,000 population	Mandate
New Hampshire	2004	Requires referendum	Procedural
New Jersey	None		N/A
New Mexico	None		N/A
New York	None		N/A
North Carolina	None		N/A
North Dakota	None		N/A
Ohio	1969	Fluoridation required in communities over 5,000 population (cities were allowed to opt out via referendum within 240 days of enaction)	Mandate
Oklahoma	None		N/A
Oregon	None		N/A
Pennsylvania	None		N/A
Rhode Island	None		N/A
South Carolina	None		N/A
South Dakota	1969	Requires fluoridation of all public water supplies in communities of 500 or more	Mandate
Tennessee	None		N/A
Texas	None		N/A
Utah		Referendum required to adopt fluoridation	Procedural
Vermont	None		N/A
Virginia	None		N/A
Washington	None		N/A
West Virginia	None		N/A

State	Date Law Enacted	Summary of Law	Category
Wisconsin	None		N/A
Wyoming	None		N/A

APPENDIX B. UNSUCCESSFUL FLUORIDATION LEGISLATION

State	Date Attempted	Summary of Legislation
Arkansas	2005	Required communities over 5,000 population to fluoridate
Hawai'i	1955	Required fluoridation of all community water supplies
	1987	Required fluoridation of all community water supplies
	2000	Required fluoridation of all community water supplies
Kansas	2004	Required fluoridation of Wichita and Hutchinson (largest unfluoridated cities)
Nebraska	2005	Mandated fluoridation in communities over 1,000 and prohibited fluoridation referenda
New Jersey	2003	Required fluoridation of all community water systems
Oregon	1976	(Referendum) Prohibited fluoridation of community water supplies
	1999	Required fluoridation in communities over 10,000
	2005	Required fluoridation in communities over 10,000
Pennsylvania	2007	Required fluoridation of water systems over 500 customers
Washington	1976	(Referendum) Prohibited fluoridation of community water supplies

APPENDIX C. MEASURES OF CARIES PREVALENCE

State	Caries Measure
Alabama	N/A
Alaska	DMFT Head Start 3-5 yr. olds
Arizona	DFT K-3 grade
Arkansas	DFT and untreated decay 3rd grade
California	DFT and untreated decay 3rd grade
Colorado	DFT and untreated decay 3rd grade
Connecticut	N/A
Delaware	DFT and untreated decay 3rd grade
Florida	N/A
Georgia	DFT and untreated decay 3rd grade
Hawai'i	DFT 5-9 yrs; DMFT 8 yrs
Idaho	DFT & DMFT 2nd graders
Illinois	DFT and untreated decay 3rd grade
Indiana	1992-1993 latest data available
Iowa	DFT and untreated decay 3rd grade
Kansas	DFT and untreated decay 3rd grade
Kentucky	DFT and untreated decay 3rd & 6th grade
Louisiana	N/A
Maine	DFT and untreated decay 3rd grade
Maryland	DFT and untreated decay 3rd grade
Massachusetts	N/A
Michigan	DFT and untreated decay 3rd grade
Minnesota	N/A
Mississippi	DFT and untreated decay 3rd grade
Missouri	DFT and untreated decay 3rd grade
Montana	N/A
Nebraska	DFT and untreated decay 3rd grade
Nevada	DFT and untreated decay 3rd grade
New Hampshire	DFT and untreated decay 3rd grade
New Jersey	N/A
New Mexico	DFT and untreated decay 3rd grade
New York	DFT and untreated decay 3rd grade
North Carolina	1986-1987 latest survey conducted

State	Caries Measure
North Dakota	DFT and untreated decay 3rd grade
Ohio	DFT and untreated decay 3rd grade
Oklahoma	DFT and untreated decay 3rd grade
Oregon	DFT and untreated decay 1st & 3rd grade
Pennsylvania	DFT and untreated decay 3rd grade
Rhode Island	N/A
South Carolina	DFT and untreated decay K and 3rd grade
South Dakota	DFT and untreated decay 3rd grade
Tennessee	N/A
Texas	N/A
Utah	DFT and untreated decay grades 1-3
Vermont	DFT and untreated decay grades 1-3
Virginia	N/A
Washington	DFT and untreated decay grades 1-2
West Virginia	N/A
Wisconsin	DFT and untreated decay 3rd grade
Wyoming	N/A

APPENDIX D. SURVEY QUESTIONNAIRE

Questions for state oral health directors

Name and position of responding individual:

Consent

_____________ I have read and understand the information in the consent form, and I agree to participate in this research project.

Confidentiality: please choose one

_____________ I hereby request that my responses to this questionnaire be kept confidential.

_____________ I hereby authorize the use of my responses with personal identifying information and do not request that my responses be kept confidential.

****

For how long has a position for a full-time oral health director existed in your state?

On a scale of 1-5, with 1 = very important and 5 = not important at all, how does community water fluoridation currently rank as a priority for the oral health department in your state?

Is the promotion of community water fluoridation part of an overall public health plan or oral health plan in your state?

Has the relative importance of community water fluoridation increased, decreased, or remained the same in your state over the past twenty-five years?

Please list methods used by your state's oral health department to promote fluoridation, either currently or in the past.

Is state funding is available for water fluoridation promotion, equipment, and/or personnel?

If so, please give an estimate of the amount that is currently available.

Please list other sources of funding for water fluoridation available in your state (e.g., funds from private organizations, funds from city/county governments, funds from the state dental association).

What, in your opinion, are the greatest impediments to increasing the number of communities in your state that are served by community water fluoridation?

Would you be willing to share your state's responses to the Association of State and Territorial Dental Directors' most recent *Synopsis Questionnaire*?

If so, please send as an email attachment.

May the investigator contact you by telephone with follow-up questions?

If so, please provide a contact telephone number and best times to call.

APPENDIX E. PERCENT OF COUNTIES WITHOUT A DENTIST, PERCENT OF CHILDREN ENROLLED IN MEDICAID/SCHIP, PERCENT OF DENTISTS WHO ACCEPT MEDICAID, 2002-2007

State	Percent of Counties without a Dentist	Percent of Children Enrolled in Medicaid/SCHIP	Percent of Dentists Who Accept Medicaid
Alabama	3	28.70	36
Alaska	na	40.60	91
Arizona	0	26.90	30
Arkansas	4	38.50	59
California	2	29.50	83
Colorado	18	17.10	25
Connecticut	0	19.10	14
Delaware	na	24.20	39
Florida	3	26.40	14
Georgia	na	26.80	55
Hawai'i	0	21.80	30
Idaho	11	29.60	100
Illinois	5	20.30	24
Indiana	0	20.80	63
Iowa	0	18.00	95
Kansas	10	19.20	45
Kentucky	1	27.30	43
Louisiana	3	31.50	39
Maine	0	35.20	43
Maryland	na	19.20	na
Massachusetts	0	20.30	14
Michigan	1	27.00	30
Minnesota	na	18.60	75
Mississippi	5	39.90	50
Missouri	4	26.90	1
Montana	22	33.00	72
Nebraska	19	21.20	100
Nevada	19	19.90	46

State	Percent of Counties without a Dentist	Percent of Children Enrolled in Medicaid/SCHIP	Percent of Dentists Who Accept Medicaid
New Hampshire	0	17.10	43
New Jersey	0	15.90	40
New Mexico	3	50.80	52
New York	2	31.10	43
North Carolina	4	31.00	41
North Dakota	na	21.50	45
Ohio	1	23.00	32
Oklahoma	5	31.50	40
Oregon	na	25.10	80
Pennsylvania	na	21.90	27
Rhode Island	0	25.80	78
South Carolina	na	28.20	51
South Dakota	29	28.50	95
Tennessee	1	24.80	18
Texas	18	30.40	17
Utah	7	16.00	45
Vermont	0	37.80	93
Virginia	4	17.90	19
Washington	0	32.90	29
West Virginia	na	37.70	89
Wisconsin	0	25.90	56
Wyoming	na	30.00	65

Compiled from *Synopses of state and territorial dental public health programs*

(Centers for Disease Control National Center for Chronic Disease Prevention and Health Promotion 2005)

APPENDIX F. PERCENT OF POPULATION ON PUBLIC WATER SUPPLIES RECEIVING NATURALLY OPTIMALLY FLUORIDATED WATER, 1985 AND 2005

State	1985	2005
Alabama	1.5	1.8
Alaska	0	na
Arizona	12.7	na
Arkansas	0.7	0.4
California	0	na
Colorado	23.4	2.7
Connecticut	0	na
Delaware	0.8	1.3
Florida	6.8	9.0
Georgia	0.3	0.3
Hawai'i	0	0.0
Idaho	18.5	27.4
Illinois	8.2	3.2
Indiana	4.8	7.4
Iowa	11.3	12.8
Kansas	5.4	na
Kentucky	0	1.9
Louisiana	5.1	5.5
Maine	0	0.0
Maryland	1.1	na
Massachusetts	0	0.0
Michigan	1.4	2.6
Minnesota	0	0.1
Mississippi	2.8	4.3
Missouri	3.1	na
Montana	12.7	na
Nebraska	1.1	3.0
Nevada	1.6	5.6
New Hampshire	1.1	6.8
New Jersey	1.5	na
New Mexico	16.7	na

State	1985	2005
New York	0	na
North Carolina	1.3	7.4
North Dakota	4.3	1.7
Ohio	2.2	1.6
Oklahoma	3.3	na
Oregon	1.5	na
Pennsylvania	0	0.0
Rhode Island	0	na
South Carolina	10.7	3.5
South Dakota	5.9	na
Tennessee	0	0.0
Texas	15.5	15.3
Utah	0.3	na
Vermont	0	0.0
Virginia	3.7	5.5
Washington	1.3	na
West Virginia	0	0.7
Wisconsin	3.7	5.9
Wyoming	4.2	na

APPENDIX G. STATE VARIABLES

State	CDC Fluoridation Category, 2002	Percent of Third Graders with Caries Experience, 1999-2005	Percent of Children Eligible for Medicaid or SCHIP, 2005	Percent of State Population Classified as Rural, 2000	FT Dental Director	Fluoridation in State Plan	Percent of Counties without a Dentist, 2005
Alabama	4	na	28.70	43.20	Y	N	3
Alaska	3	65.10	40.60	39.00	Y	Y	na
Arizona	3	66.70	26.90	13.50	Y	N	0
Arkansas	3	72.20	38.50	48.00	Y	Y	4
California	2	70.90	29.50	6.30	N	N	2
Colorado	4	57.20	17.10	16.20	Y	Y	18
Connecticut	4	na	19.10	13.00	N	N	0
Delaware	4	54.50	24.20	20.80	Y	Y	na
Florida	3	na	26.40	12.00	Y	Y	3
Georgia	4	56.30	26.80	31.30	Y	N	na
Hawai'i	1	na	21.80	9.50	Y	N	0
Idaho	2	65.40	29.60	37.80	Y	Y	11
Illinois	4	55.40	20.30	13.60	Y	Y	5
Indiana	4	na	20.80	30.90	Y	N	0
Iowa	4	49.60	18.00	40.60	N	Y	0
Kansas	3	58.60	19.20	30.50	N	Y	10
Kentucky	4	59.80	27.30	40.10	Y	N	1
Louisiana	3	na	31.50	27.10	Y	N	0
Maine	4	44.70	35.20	57.40	Y	Y	3

State	CDC Fluoridation Category, 2002	Percent of Third Graders with Caries Experience, 1999-2005	Percent of Children Eligible for Medicaid or SCHIP, 2005	Percent of State Population Classified as Rural, 2000	FT Dental Director	Fluoridation in State Plan	Percent of Counties without a Dentist, 2005
Maryland	4	42.40	19.20	15.00	N	N	na
Massachusetts	3	48.80	20.30	9.50	Y	N	0
Michigan	4	58.00	27.00	24.80	N	Y	1
Minnesota	4	na	18.60	31.00	Y	N	na
Mississippi	2	68.90	39.90	50.90	Y	N	5
Missouri	4	54.70	26.90	30.40	Y	Y	4
Montana	1	na	33.00	43.60	Y	N	22
Nebraska	4	59.30	21.20	32.80	Y	Y	19
Nevada	3	67.10	19.90	12.60	Y	Y	19
New Hampshire	2	52.00	17.10	42.80	Y	Y	0
New Jersey	1	na	15.90	6.50	Y	N	0
New Mexico	4	64.60	50.80	25.00	Y	N	3
New York	3	54.10	31.10	12.60	Y	N	2
North Carolina	4	na	31.00	42.20	Y	N	4
North Dakota	4	55.60	21.50	46.60	Y	Y	na
Ohio	4	na	23.00	22.50	Y	Y	1
Oklahoma	3	69.40	31.50	34.80	Y	N	5
Oregon	1	60.70	25.10	25.10	N	Y	na
Pennsylvania	3	52.60	21.90	23.20	Y	Y	na
Rhode Island	4	na	25.80	10.10	Y	Y	0
South Carolina	4	57.90	28.20	38.50	Y	Y	na
South Dakota	4	66.90	28.50	49.70	Y	N	29

State	CDC Fluoridation Category, 2002	Percent of Third Graders with Caries Experience, 1999-2005	Percent of Children Eligible for Medicaid or SCHIP, 2005	Percent of State Population Classified as Rural, 2000	FT Dental Director	Fluoridation in State Plan	Percent of Counties without a Dentist, 2005
Tennessee	4	na	24.80	37.30	Y	Y	1
Texas	3	na	30.40	18.80	Y	N	18
Utah	1	61.00	16.00	13.20	Y	Y	7
Vermont	3	45.10	37.80	59.80	Y	Y	0
Virginia	4	na	17.90	28.50	Y	N	4
Washington	3	59.70	32.90	20.10	N	N	0
West Virginia	4	na	37.70	53.10	N	N	na
Wisconsin	4	60.10	25.90	32.70	Y	N	0
Wyoming	2	na	30.00	32.90	Y	N	na

APPENDIX H. STATE FLUORIDATION DATA

State	Percent of Population Receiving Optimally Fluoridated Water, 2005	Percent of Population Receiving Naturally Optimally Fluoridated Water, 2002	Percent of Population Receiving Optimally Adjusted Fluoridated Water, 2002	Percent of Population Not on Public Water Supplies, 2000	Percent of Population on Public Water Supplies Receiving Optimally Fluoridated Water, 2002	CDC Fluoridation Category, 2002
Alabama	89.20	1.80	82.00	20.00	82.00	4
Alaska	55.20	na	55.20	33.00	57.30	3
Arizona	55.50	na	55.50	5.00	55.40	3
Arkansas	59.90	0.40	63.90	13.00	62.10	3
California	28.70	na	28.70	11.00	27.60	2
Colorado	76.90	2.70	71.10	13.00	75.40	4
Connecticut	88.80	na	88.80	22.00	87.60	4
Delaware	80.90	1.30	75.30	21.00	80.90	4
Florida	62.60	9.00	67.10	12.00	67.40	3
Georgia	92.90	0.30	95.50	18.00	93.00	4
Hawai'i	9.00	0.00	9.00	6.00	8.60	1
Idaho	45.40	27.40	3.80	28.00	47.50	2
Illinois	93.40	3.20	95.80	12.00	99.10	4
Indiana	95.30	7.40	88.00	26.00	95.50	4
Iowa	91.30	12.80	79.00	17.00	91.30	4
Kansas	62.50	na	62.50	7.00	62.10	3

State	Percent of Population Receiving Optimally Fluoridated Water, 2005	Percent of Population Receiving Naturally Optimally Fluoridated Water, 2002	Percent of Population Receiving Optimally Adjusted Fluoridated Water, 2002	Percent of Population Not on Public Water Supplies, 2000	Percent of Population on Public Water Supplies Receiving Optimally Fluoridated Water, 2002	CDC Fluoridation Category, 2002
Kentucky	96.10	1.90	97.80	14.00	99.60	4
Louisiana	53.20	5.50	37.00	12.00	45.90	3
Maine	75.40	0.00	80.30	43.00	74.40	4
Maryland	90.70	na	90.70	18.00	93.70	4
Massachusetts	55.80	0.00	59.10	7.00	60.70	3
Michigan	90.70	2.60	88.80	28.00	86.20	4
Minnesota	98.20	0.10	98.30	23.00	98.40	4
Mississippi	46.00	4.30	47.80	23.00	46.10	2
Missouri	80.50	na	80.50	15.00	80.90	4
Montana	22.20	na	22.20	26.00	23.80	1
Nebraska	77.70	3.00	66.80	19.00	69.50	4
Nevada	65.90	5.60	68.70	6.00	69.40	3
New Hampshire	38.40	6.80	38.40	39.00	42.70	2
New Jersey	15.50	na	15.50	11.00	20.80	1
New Mexico	76.70	na	76.70	20.00	76.60	4
New York	67.80	na	72.40	10.00	72.90	3
North Carolina	83.30	7.40	79.50	34.00	84.60	4
North Dakota	95.40	1.70	95.10	23.00	95.60	4
Ohio	87.60	1.60	72.00	16.00	90.60	4
Oklahoma	74.60	na	87.60	9.00	74.60	3

State	Percent of Population Receiving Optimally Fluoridated Water, 2005	Percent of Population Receiving Naturally Optimally Fluoridated Water, 2002	Percent of Population Receiving Optimally Adjusted Fluoridated Water, 2002	Percent of Population Not on Public Water Supplies, 2000	Percent of Population on Public Water Supplies Receiving Optimally Fluoridated Water, 2002	CDC Fluoridation Category, 2002
Oregon	23.90	na	19.40	20.00	19.40	1
Pennsylvania	54.20	0.00	54.00	18.00	54.00	3
Rhode Island	85.10	na	85.10	12.00	89.20	4
South Carolina	91.20	3.50	89.20	21.00	91.40	4
South Dakota	88.40	na	88.40	17.00	78.00	4
Tennessee	94.50	0.00	94.00	8.00	96.00	4
Texas	65.70	15.30	62.60	6.00	65.70	3
Utah	2.00	na	2.00	3.00	2.20	1
Vermont	54.20	0.00	58.70	41.00	55.70	3
Virginia	93.30	5.50	89.20	25.00	93.80	4
Washington	57.80	na	57.80	17.00	58.90	3
West Virginia	87.00	0.70	90.20	28.00	91.50	4
Wisconsin	89.30	5.90	83.80	33.00	89.40	4
Wyoming	30.30	na	30.30	18.00	36.70	2

APPENDIX I. DATA FOR OHIO COUNTIES

County Name	Percent of Population Receiving Optimally Fluoridated Water, 2007	CDC Fluoridation Category	Population, 2000	Percent of Third-Graders with Caries Experience, 2007	Percent of Children Eligible for Medicaid	Percent of Population Below Poverty Level	Metro Code
Adams	91.80	4	27330	55.9	55.6	16.1	0
Allen	100.00	4	108473	25.3	32.1	12.2	1
Ashland	76.00	4	52523	26.4	26.5	9.7	0
Ashtabula	96.60	4	102728	35.1	41.0	12.7	0
Athens	97.50	4	62223	26.5	37.2	20.2	0
Auglaize	66.80	3	46611	28.4	18.4	7.0	0
Belmont	95.90	4	70226	27.3	43.0	14.8	1
Brown	82.70	4	42285	46.5	35.3	11.9	1
Butler	99.50	4	332807	31.7	25.1	9.8	1
Carroll	46.60	2	28836	34.0	37.8	10.9	1
Champaign	23.10	1	38890	18.9	28.3	8.9	0
Clark	26.70	2	144742	24.9	38.8	12.8	1
Clermont	95.00	4	177977	33.9	24.8	7.8	1
Clinton	15.00	1	40543	20.4	31.3	9.8	0
Columbiana	88.40	4	112075	27.9	42.8	12.2	0
Coshocton	78.20	4	36655	31.4	38.3	11.3	0

County Name	Percent of Population Receiving Optimally Fluoridated Water, 2007	CDC Fluoridation Category	Population, 2000	Percent of Third-Graders with Caries Experience, 2007	Percent of Children Eligible for Medicaid	Percent of Population Below Poverty Level	Metro Code
Crawford	46.90	2	46966	43.8	38.9	11.4	0
Cuyahoga	100.00	4	1393978	36.5	42.0	15.0	1
Darke	13.30	1	53309	13.1	23.1	8.3	0
Defiance	100.00	4	39500	17.5	27.6	7.9	0
Delaware	98.60	4	109989	11.5	12.4	5.0	1
Erie	98.90	4	79551	20.2	29.1	9.6	1
Fairfield	41.90	2	122759	15.8	27.7	7.7	1
Fayette	29.20	2	28433	26.9	37.3	12.0	0
Franklin	99.00	4	1068978	13.3	36.1	13.1	1
Fulton	95.70	4	42084	14.3	23.0	7.1	1
Gallia	98.00	4	31069	37.8	51.7	17.4	0
Geauga	51.70	3	90895	18.3	10.8	5.5	1
Greene	68.20	3	147886	30.1	21.5	9.4	1
Guernsey	96.70	4	40792	30.4	47.9	15.2	0
Hamilton	99.30	4	845303	32.0	na	13.1	1
Hancock	100.00	4	71295	14.7	21.5	7.9	0
Hardin	100.00	4	31945	34.7	27.7	11.6	0
Harrison	71.40	3	15856	65.3	45.4	13.0	0
Henry	100.00	4	29210	14.8	24.6	7.3	0
Highland	85.60	4	40875	31.9	40.5	12.2	0
Hocking	92.90	4	28241	32.3	48.1	13.3	0

County Name	Percent of Population Receiving Optimally Fluoridated Water, 2007	CDC Fluoridation Category	Population, 2000	Percent of Third-Graders with Caries Experience, 2007	Percent of Children Eligible for Medicaid	Percent of Population Below Poverty Level	Metro Code
Holmes	.00	1	38943	29.2	13.0	9.7	0
Huron	91.40	4	59487	18.9	32.1	9.5	0
Jackson	100.00	4	32641	51.6	53.2	15.5	0
Jefferson	79.40	4	73894	26.8	43.6	14.7	1
Knox	26.60	2	54500	14.5	29.7	10.6	0
Lake	99.90	4	227511	19.7	19.6	6.6	1
Lawrence	85.40	4	62319	46.3	54.5	17.4	1
Licking	78.00	4	145491	11.6	30.0	9.5	1
Logan	80.30	4	46005	36.7	30.2	10.0	0
Lorain	99.40	4	284664	27.2	31.0	10.9	1
Lucas	100.00	4	455054	16.2	74.8	14.7	1
Madison	98.60	4	40213	21.6	25.8	9.6	1
Mahoning	99.70	4	257555	26.8	39.0	14.3	1
Marion	100.00	4	66217	38.3	38.3	12.0	0
Medina	91.60	4	151095	15.2	15.3	5.9	1
Meigs	51.00	3	23072	42.6	53.5	18.1	0
Mercer	47.90	2	40924	15.5	15.4	6.4	0
Miami	39.90	2	98868	23.1	23.3	8.2	1
Monroe	41.10	2	15180	35.0	53.4	12.4	0
Montgomery	96.30	4	559062	20.2	33.7	12.5	1
Morgan	.00	1	14897	19.3	51.9	14.8	0

County Name	Percent of Population Receiving Optimally Fluoridated Water, 2007	CDC Fluoridation Category	Population, 2000	Percent of Third-Graders with Caries Experience, 2007	Percent of Children Eligible for Medicaid	Percent of Population Below Poverty Level	Metro Code
Morrow	79.40	4	31628	48.1	33.5	9.8	1
Muskingum	86.10	4	84585	27.5	44.6	14.2	0
Noble	100.00	4	14058	28.8	40.2	13.2	0
Ottawa	88.30	4	40985	14.3	28.5	7.5	1
Paulding	98.80	4	20293	13.7	29.0	8.7	0
Perry	89.60	4	34078	27.3	47.1	13.2	0
Pickaway	75.30	4	52727	22.7	32.6	11.1	1
Pike	84.80	4	27695	48.1	60.1	17.2	0
Portage	85.30	4	152061	21.5	23.5	9.7	1
Preble	76.20	4	42337	19.6	27.5	8.1	1
Putnam	100.00	4	34726	6.3	16.3	6.5	0
Richland	19.50	1	128852	39.1	36.0	12.0	1
Ross	85.00	4	73345	31.4	46.7	13.1	0
Sandusky	100.00	4	61792	27.8	29.2	8.9	0
Scioto	100.00	4	79195	45.2	52.9	18.9	0
Seneca	96.90	4	58683	23.2	29.0	9.8	0
Shelby	94.10	4	47910	12.3	24.0	7.8	0
Stark	94.70	4	378098	30.3	32.1	10.7	1
Summit	97.80	4	542899	25.3	31.1	12.3	1
Trumbull	97.30	4	225116	28.7	36.3	12.1	1
Tuscarawas	15.70	1	90914	33.7	31.8	10.1	0

County Name	Percent of Population Receiving Optimally Fluoridated Water, 2007	CDC Fluoridation Category	Population, 2000	Percent of Third-Graders with Caries Experience, 2007	Percent of Children Eligible for Medicaid	Percent of Population Below Poverty Level	Metro Code
Union	100.00	4	40909	na	21.2	6.7	1
Van Wert	95.70	4	29659	22.7	25.3	7.0	0
Vinton	46.10	2	12806	43.5	57.6	16.8	0
Warren	80.30	4	158383	21.3	12.3	5.3	1
Washington	82.00	4	63251	27.9	35.2	12.2	1
Wayne	27.90	2	111564	25.4	23.8	9.1	0
Williams	100.00	4	39188	21.0	29.9	8.3	0
Wood	95.70	4	121065	19.8	17.9	8.0	1
Wyandot	68.10	3	22908	36.7	21.4	6.6	0

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