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## Caries Incidence and Costs of Prevention Programs

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### Abstract

*Data on caries increments and costs of prevention programs are presented as background information for participants in the workshop. Estimates of annual caries increments were derived from control groups in clinical trials, epidemiologic studies, and national surveys. Cost data were obtained from dental public health directors, program administrators, fluoridation engineers, and water plant operators in different parts of the US. Caries incidence data are reported for age groups: 5-17 years (fluoridated and nonfluoridated areas), 18-44 years, 45-64 years, and 65 and over. Program costs include direct costs primarily and do not allow for program inefficiencies, nor have they attempted to include social costs. All cost data are expressed in 1988 dollars. Direct program costs are included for community water fluoridation, fluoride supplements, fluoride mouthrinses, school fluoridation, and sealant programs. For professionally and self-applied fluoride programs, only material and salary costs are included because total costs could not be located in the literature nor obtained from program directors. All factors and necessary assumptions included in the cost assessments are described.*

**Key Words:** *caries incidence, costs of prevention, dental public health.*

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This report presents the data collected for use by the work groups as part of their source material. The data are presented in two sections: the first summarizes pertinent information on caries experience in children, adults, and the elderly in the US and Canada over the last ten years; the second includes reported costs of six types of caries prevention programs currently in effect throughout the United States. This paper is not intended to be a comprehensive review of the literature, nor an exhaustive account of caries prevention programs in the United States. Rather, it is intended to be a reasonably representative selection of recent data from a number of sources, sufficient to provide sound basic information on which the work groups can base their calculations.

### A. Caries Incidence

Included in this section are incidence data from control

groups in caries clinical trials and community trials, together with imputed incidence from epidemiologic surveys conducted in the US and Canada since 1978. Caries experience data for children, adults, and the elderly are summarized in Tables 1-7.

Four criteria were used to select the studies for this review: date of the study, type of experimental design, length of the trial, and completeness of the published reports. Because the results of studies performed during the early 1970s would probably not portray a realistic picture of caries experience today, the first criterion was to limit the studies to those conducted in recent years. Although a number of studies published in the late 1970s met this criterion, they were not included in the review because data had been collected up to ten years earlier, making them too old for use in the workshop. Deriving incidence data from clinical trials required that caries increments be reported for study participants not receiving the preventive regimens being tested, that is, control groups. Thus, the second criterion tended to exclude demonstration projects and studies using historical comparisons or cross-sectional controls.

The third criterion was needed in view of the recognized caries decline in recent years. As the period of time required for caries development increases, longer clinical trials are needed. Hence, studies of a minimum duration of two years were selected. It should be noted that two exceptions to this rule were made in the 45-64 and 65+ age categories (Kohout F, College of Dentistry and the Center for Health Services Research, University of Iowa; Papas A, Joshi A, Tufts University School of Dental Medicine, Boston. All personal communications, Feb 1989). Both studies, conducted for less than two years, were included in Tables 6-7 because of the sparse information for these age groups.

Finally, details regarding the conduct of the trial, such as the selection of subjects, study protocol, diagnostic criteria, and analysis of data were used to judge the quality of the various studies. Studies published only as abstracts have therefore been omitted from this report.

**Children: Aged 5-17.** Estimates of annual caries increments for children aged 5-17 were derived from the control groups of studies summarized in Tables 1-4. While control group participants would not have been affected by the preventive intervention under study, they

**A. CARIES INCIDENCE: TABLE 1**  
**Caries Experience of Children Aged 5-15 from fluoride-deficient Communities in the US and Canada: Annual DMFS**  
**Increments of Controls from Caries Clinical Trials, 1978-88\***

Authors and Year	Type of Trial	Age at Baseline	N	Location	Length of Study (Years)	Annual DMFS Increment
NPDDP <sup>1</sup> 1977-78 to 1981-82	Combined treatment	6-7	740	MA, FL, KS†, LA, WA	4.0	0.8
NPDDP <sup>1</sup> 1977-78 to 1981-82	Combined treatment	appr. 10	296	MA, FL, KS†, LA, WA	4.0	1.2
Ripa et al. <sup>2</sup> 1979-82	APF gel	10-13	324	Long Island, NY	3.0	1.1**
Abrams and Chambers <sup>3</sup> (1980)	Dentifrice	5-12	380	San Francisco, CA	3.0	2.6
Triol et al. <sup>4</sup> (1980)	Dentifrice & mouthrinse	10-13	266	Brookline, MA	2.5	1.2‡
Glass <sup>5</sup> (1981)	Dentifrice	6-11	211	MA	2.5	2.0***
Clark et al. <sup>6</sup> 1981-86	Fluoride varnish	6-7	189	Quebec, Canada	4.7	0.9
Ringelberg et al. <sup>7</sup> (1982)	Fluoride mouthrinse	12.5	249	Polk County, FL	2.0	1.7
Heifetz et al. <sup>8</sup> (1982)	Fluoride mouthrinse	10-12	87	Biddeford, ME	3.0	1.2††
			117			1.5
Ripa et al. <sup>9</sup> 1982-85	Dentifrice	9-15	827	Long Island, NY	3.2	1.2‡
Burt et al. <sup>10</sup> 1982-85	Diet study	10-15	499	Coldwater, MI	3.0	1.0
Glass <sup>11</sup> (1983)	Sorbitol	7-11	271	MA	2.0	2.4***
Lu et al. <sup>12</sup> (1987)	Dentifrice	7-15	703	Portland, OR	3.0	1.5‡
Conti et al. <sup>13</sup> (1988)	Dentifrice	7-14	1,228	Polk County, FL	3.0	0.8‡
All						Mean=1.4 Median=1.2 Range=0.8-2.6

\*Trials are listed according to date of study if known; otherwise, publication date (in parentheses) is used.

†0.4 ppm fluoride.

\*\*Positive control (biannual APF gel).

‡Positive control group (1,000-1,100 ppm F/dentifrice).

\*\*\*DFS rate.

††Reports from two different examiners.

**TABLE 2**  
**Caries Experience of Children Aged 6-15 from Fluoride-deficient Communities in the US and Canada: Surface-specific**  
**DMFS Increments of Controls from Caries Clinical Trials, 1978-86\***

Authors and Year	Age at Baseline	N	Length of Study (Years)	Annual DMFS Increments			
				Proximal	Buccolingual	Occlusal	Total
NPDDP <sup>1</sup> 1978-82	6-7	740	4.0	0.10	0.25	0.43	0.78
NPDDP <sup>1</sup> 1978-82	~10	296	4.0	0.27	0.26	0.65	1.18
Ripa et al. <sup>2</sup> 1979-82	10-13	324	3.0	0.20	0.29	0.62	1.11
Clark et al. <sup>6</sup> 1981-86	6-7	189	4.7	0.13	0.27	0.53	0.93
Heifetz et al. <sup>8</sup> (1982)†	10-12	87	3.0	0.46	0.24	0.50	1.20
		117		0.57	0.34	0.57	1.48
Ripa et al. <sup>9</sup> 1982-85	9-15	827	3.2	0.23	0.28	0.65	1.16
All				Mean=0.3	0.3	0.6	1.1
				Median=0.2	0.3	0.6	1.2
				Range=0.1-0.6	0.2-0.3	0.4-0.7	0.8-1.5

\*Trials are listed according to date of study; if unknown, publication date (in parentheses) is used.

†Results of two examiners.

**TABLE 3**  
**Caries Experience of Children Aged 6-13 from Fluoridated Communities in the US: Annual DMFS Increments of Controls from Caries Clinical Trials, 1978-84\***

Authors and Year	Material	Age at Baseline	N	Location	Duration (Years)	Annual DMFS Increment
Bagramian et al. <sup>14</sup> 1973-78	Combined treatment	6-7	199	Ypsilanti, MI	5.0	0.5
Bagramian et al. <sup>14</sup> 1973-78	Combined treatment	11-12	130	Ypsilanti, MI	5.0	0.9
Driscoll et al. <sup>15</sup> 1977-80	Mouthrinse	12-13	151	Des Moines, IA	2.5	0.9†
NPDDP <sup>1</sup> 1978-82	Combined treatment	6-7	431	NY, TN, MN, TX, CA**	4.0	0.6
NPDDP <sup>1</sup> 1978-82	Combined treatment	~10	204	NY, TN, MN, TX, CA**	4.0	0.8
Glass et al. <sup>16</sup> (1983)	Dentifrice	7-11	286	—	2.5	1.1†
Fogels et al. <sup>17</sup> 1981-84	Dentifrice	6-11	950	Boston, MA	3.0	0.8‡
All						Mean=0.8 Median=0.8 Range=0.5=1.1

\*Trials are listed according to date of study if known; otherwise, publication date (in parentheses) is used.

†Average of 2 examiners.

\*\*Intermittent fluoridation during the 1970s.

‡Positive control group (1,000 ppm dentifrice).

**TABLE 4**  
**Caries Experience of Children Aged 6-13 from Fluoridated Communities in the US: Surface-specific DMFS Increments of Controls from Caries Clinical Trials, 1973-82**

Authors and Year	Age at Baseline	N	Length of Study (Years)	Annual DMFS Increments			
				Proximal	Buccolingual	Occlusal	Total
Bagramian et al. <sup>14</sup> 1973-78	6-7	199	5.0	0.04	0.14	0.28	0.46
Bagramian et al. <sup>14</sup> 1973-78	11-12	130	5.0	0.30	0.14	0.46	0.90
Driscoll et al. <sup>15</sup> 1977-80	12-13	151	2.5	0.14	0.20	0.56	0.90
NPDDP <sup>1</sup> 1978-82	6-7	431	4.0	0.04	0.18	0.33	0.55
NPDDP <sup>1</sup> 1978-82	~10	204	4.0	0.07	0.19	0.51	0.77
All				Mean=0.1	0.2	0.4	0.7
				Median=0.1	0.2	0.5	0.8
				Range=0.04-0.3	0.1-0.2	0.3-0.6	0.5-0.9

probably received benefits from uncontrolled home use of fluoridated dentifrices or from other preventive dental care. From the 17 studies listed in Tables 1-4, only three required participants in control groups to use a non-fluoridated dentifrice (3,5,16). Consequently, the caries experience of the remaining control groups (or positive controls) from these trials is likely to reflect the preventive effects of the widespread use of fluorides in the 1980s.

Surface-specific increments were available for a few of the studies, and are recorded in Tables 2 and 4. Studies have been listed separately for fluoride-deficient (1-13) and fluoridated communities (1,14-17). Areas of less than 0.3 ppm of fluoride in their water supplies were considered "fluoride-deficient" communities; "fluoridated" communities include areas with optimal fluoride levels for their region ranging from 0.8 to 1.1 ppm fluoride.

Annual caries incidence was calculated as mean, median, and range of decayed, missing, and filled surfaces (DMFS) increment/year. Imputed incidence from national surveys suggests these increments are reasonable estimates for children and young adults.

**Adults: Aged 18-44, 45-64, and 65+.** While the caries experience of children is well documented, very limited information exists in the literature about the caries incidence of adults. Thus, estimates for these age groups were derived not only from the few studies available (18-20,22-23), but also imputed from the 1985-86 National Survey of Employed Adults and Seniors (21).

Caries experience data for adults aged 18-44, 45-64, and 65+ are presented in Tables 5-7. The information in these tables must be interpreted with caution for several reasons. First, the number of available studies is sufficient

**TABLE 5**  
**Caries Experience of Adults Aged 18-44 in the US, 1969-86: Annual Caries Increments from Longitudinal, Retrospective Studies, Controls from a Clinical Trial, and the 1985-86 NIDR Survey\***

Authors and Year	Age at Baseline	N	Length of Study (Years)	Annual DMFS Increment
Glass et al. <sup>18</sup> (1969-70 to 1979-80)	<45†	262	10	1.06**
Hyman <sup>19</sup> (1983)	21.2	120	<4‡	1.38
	30.2	102	>4‡	1.59
	20-24	18	3.0	0.91
Ripa & Leske <sup>20</sup> 1983-86	25-34	88		0.71
	35-44	107		0.75
	18-44	9,619	23.5	1.16
NIDR <sup>21</sup> 1985-86				Mean=1.1
All				Median=1.1
				Range=0.7-1.6

\*Listed according to the years during which study was conducted, or by publication date (in parentheses).

†Age at end of study.

\*\*Average DFS rate per 100 surfaces at risk; root caries included for one-third of subjects.

‡Retrospective study of existing dental records.

**TABLE 6**  
**Caries Experience of Adults Aged 45-64 in the US, 1969-87: Annual DMFS Increments from the 1985-86 NIDR Adult Survey, a Longitudinal Study, and Controls from a Clinical Trial\***

Authors and Year	Age at Baseline	N	Length of Study (Years)	Annual DFS Increments		
				Coronal	Root	Total
Glass et al. <sup>18</sup> (1987)	45-54†	321	10			1.43**
	≥55†	146				1.76**
Ripa and Leske <sup>20</sup> (1987)	45-65	137	3	0.91	0.3	1.21‡
NIDR <sup>21</sup> 1985-86	45-64+	5,513	15	0.69	0.66	1.35‡
Kohout*** 1989	<60	36	1	1.69	0.25	1.90
	60-64	110		1.20	0.33	1.53
All				Mean=1.1	0.4	1.5
				Median=1.1	0.3	1.5
				Range=0.7-1.7	0.3-0.7	1.2-1.9

\*Listed according to the years during which study was conducted, or by publication date (in parentheses).

†Age at end of study.

\*\*Average DFS rate per 100 surfaces at risk, coronal and root caries included.

‡DMFS.

\*\*\*Personal communication, F. Kohout, 1989.

for obtaining reasonable estimates of caries experience, but not for deriving precise caries increments. Second, with the exception of national survey data (21), these studies were conducted among specific population subgroups (e.g., Navy personnel, VA patients, regional surveys) whose caries experience may not be representative of the overall adult and elderly population. Last, some researchers have cited difficulties in distinguishing coronal from root caries because a number of different criteria may have been used to define root lesions (24). Thus, the possibility that root caries was scored differently by the various examiners cannot be overlooked.

## **B. Costs of Prevention Programs**

**Derivation of Cost Data.** This section presents direct costs of six types of caries-prevention programs: water fluoridation, fluoride supplements, fluoride mouthrinse, school fluoridation, sealants, and fluoride gel applications (see Tables 8-17). It should be noted that the cost information provided in this section includes primarily direct program costs. Other expenditures such as the costs of screening, training of personnel, program promotion, and administrative costs were in most instances unavailable. Administrative and promotional costs were reported by a few states; they are summarized as

**TABLE 7**  
**Caries Incidence of Noninstitutionalized and Institutionalized Adults Aged 65 and Older in the US and Canada, 1981-88\***

Authors and Year	Age at		Length of Study (Years)	Annual DFS Increments		
	Baseline	N		Coronal	Root	Total
<b>Noninstitutionalized</b>						
Hand et al. <sup>22</sup> 1981-84	70-74	152	3.0	0.82	0.28	1.10
	75-79	90		0.87	0.35	1.22
	80+	96		0.73	0.48	1.21
NIDR <sup>21</sup> 1985	65-80+	5,649	20	1.02	0.16	1.17†
Papas and Joshi** 1988	68.8‡	88	1.3	0.75	0.74	1.49
	78.8‡	31		1.40	1.04	2.44
Kohout*** 1988	65-69	102	1	1.21	0.75	1.96
	70-74	92		1.59	0.64	2.23
	75+	94		0.96	0.64	1.60
<b>Institutionalized</b>						
Banting et al. <sup>23</sup> (1985)	68.6‡‡	45	2.8	—	0.2	
<b>All</b>				Mean=1.0	0.6	1.7
				Median=1.0	0.6	1.6
				Range=0.7-1.6	0.2-1.0	1.1-2.4

\*Listed according to the years during which study was conducted, or by publication date (in parentheses).

†DMFS.

\*\*Personal communication with Drs. A. Papas and A. Joshi.

‡Mean age.

\*\*\*Personal communication, Dr. F. Kohout, 1989.

‡‡Subjects aged 36-89 at baseline.

"other costs" and detailed below each table. All cost data are reported in 1988 dollars.

Operational costs for community water fluoridation systems shown in Tables 8-9 were gathered via mail surveys and personal communication with water plant operators and state fluoridation engineers, who also provided equipment costs from engineer specification reports. New equipment costs were obtained from vendors of fluoridation equipment and from two fluoridation engineers (Magnant ML, Iowa Department of Health, Iowa City; and Reeves TG, Centers for Disease Control, Atlanta. Both personal communications, Jan 1989). Costs of the remaining caries prevention programs reported in Tables 10-16 were obtained from state dental directors, local directors, and coordinators of specific programs across the US.

Some assumptions were required in estimating annual costs for the various programs. For community water fluoridation systems, the equipment was estimated to last 15 years and to have virtually no resale value. One-time costs such as installation, building improvements, and consulting engineering fees were included with the capital costs and the entire amount amortized over a 15-year period using 2 percent and 4 percent discount rates. This amount is the annualized or annuitized capital cost. The initial capital costs in Table 8 were adjusted for inflation to compensate for changes in the value of the dollar since the year of purchase. The adjustment factor

used is the all urban consumer price index (CPI-U), published by the Bureau of Labor Statistics in *The Monthly Labor Review*. The CPI-U, introduced in 1978, measures the average change in prices paid by urban consumers in the US for a fixed number of goods and services, and represents the buying habits of about 80 percent of the population (25). Initial capital costs in Table 9 were not adjusted for inflation because they were calculated in 1988 dollars. Annualized capital costs were added to operational costs to obtain the total direct cost per year. Annual per capita costs, calculated for 2 and 4 percent discount rates, are the total direct costs divided by the population served.

Unlike community water fluoridation, fluoride supplement programs and fluoride mouthrinse programs do not involve large capital investments. Therefore, annual program costs shown in Tables 10-12 only reflect personnel and material costs. Other costs such as travel, administration, rent, and utilities are included for some of the programs. Further cost details are discussed under each program heading.

Direct costs of school fluoridation programs are summarized in Table 13. The initial capital costs incurred by school fluoridation programs are comparable to those of community fluoridation systems. They include the cost of fluoridators, testing equipment, engineering, and installation. Consequently, similar assumptions were used to derive costs for these two types of programs. Initial

**B. COSTS OF PREVENTION PROGRAMS : TABLE 8**

**Direct Cost of Community Water Fluoridation in the US, 1988, Based on the Capital Cost of Existing Equipment (in US\$)**

State	Pop. Served	Initial Capital Cost*	Year In-curred	Initial Cost in '88 Dollars	Annual Capital Cost in '88 Dollarst		Type of Chemical	Oper. Cost/Year**	Total Direct Cost/Year		Cost/Person/Year in US Dollars	
					(2%)	(4%)			(2%)	(4%)	(2%)	(4%)
1	4,900,000	601,000	1975	1,319,296	102,675	118,659	H <sub>2</sub> SiF <sub>6</sub>	918,125	1,020,800	1,036,784	0.21	0.21
2	1,100,000	139,000	1986	149,780	11,657	13,471	H <sub>2</sub> SiF <sub>6</sub>	116,520	128,177	129,991	0.12	0.12
3	1,031,000	114,000	1973	303,230	23,599	27,273	H <sub>2</sub> SiF <sub>6</sub>	190,000	213,599	217,273	0.21	0.21
4	750,000	118,336	1986	127,514	9,924	11,469	H <sub>2</sub> SiF <sub>6</sub>	100,722	110,646	112,191	0.15	0.15
5	237,350	101,900	1983	120,827	9,403	10,867	H <sub>2</sub> SiF <sub>6</sub>	23,000	32,403	33,867	0.14	0.14
6	110,000	34,512	1973	91,799	7,144	8,256	Na <sub>2</sub> SiF <sub>6</sub>	11,553	18,697	19,809	0.17	0.18
7	28,765	19,485	1982	23,846	1,856	2,145	H <sub>2</sub> SiF <sub>6</sub>	4,930	6,786	7,075	0.24	0.25
8	20,500	9,557	1981	12,417	966	1,117	Na <sub>2</sub> SiF <sub>6</sub>	3,696	4,662	4,813	0.23	0.23
9	20,000	5,529	1978	10,015	779	901	Na <sub>2</sub> SiF <sub>6</sub>	3,491	4,270	4,392	0.21	0.22
10	13,800	13,282	1988	13,558	1,055	1,219	NaF	6,500	7,555	7,719	0.55	0.56
11	5,280	9,500	1983	11,265	877	1,013	Na <sub>2</sub> SiF <sub>6</sub>	2,779	3,656	3,792	0.69	0.72
12	2,800	10,224	1987	10,629	827	956	H <sub>2</sub> SiF <sub>6</sub>	1,718	2,545	2,674	0.91	0.95
13	2,000	5,510	1985	6,269	488	564	NaF	1,050	1,538	1,614	0.77	0.81
14	1,300	5,520	1981	7,172	558	645	NaF	567	1,125	1,212	0.87	0.93
15	800	3,828	1981	4,973	387	447	H <sub>2</sub> SiF <sub>6</sub>	312	699	759	0.87	0.95
16	498	3,567	1986	3,844	299	346	H <sub>2</sub> SiF <sub>6</sub>	234	533	580	1.07	1.16
										Mean=\$0.46	\$0.49	
										Median=0.24	0.24	
										Range=0.12-1.07	0.12-1.16	

NaF=sodium fluoride,  
H<sub>2</sub>SiF<sub>6</sub>=hydrofluosilicic acid,  
Na<sub>2</sub>SiF<sub>6</sub>=sodium silicofluoride.

\*Equipment and engineering costs. †Annualized at 2% and 4% over 15 years. \*\*Cost of chemicals, maintenance, and repair.

**TABLE 9**

**Direct Cost of Community Water Fluoridation in the US 1988, based on Equipment Replacement Costs (in US\$)**

State	Pop. Served	Initial Capital Cost ('88\$)	Annual Capital Cost in '88 Dollarst		No. Injection Points	Type of Chemical	Oper. Cost/Year**	Total Direct Cost/Year		Cost/Person/Year in US Dollars	
			(2%)	(4%)				(2%)	(4%)	(2%)	(4%)
1	4,900,000	1,262,100	98,224	113,515	2	H <sub>2</sub> SiF <sub>6</sub>	918,125	1,016,349	1,031,640	0.21	0.21
2	1,100,000	250,200	19,472	22,503	2	H <sub>2</sub> SiF <sub>6</sub>	116,520	135,992	139,023	0.12	0.13
3	1,031,000	307,800	23,955	27,684	2	H <sub>2</sub> SiF <sub>6</sub>	190,000	213,955	217,684	0.21	0.21
4	750,000	130,170	10,131	11,708	2	H <sub>2</sub> SiF <sub>6</sub>	100,722	110,853	112,430	0.15	0.15
5	237,350	173,230	13,482	15,580	2	H <sub>2</sub> SiF <sub>6</sub>	23,000	36,482	38,580	0.15	0.16
6	110,000	100,980	7,859	9,082	1	Na <sub>2</sub> SiF <sub>6</sub>	11,553	19,412	20,635	0.18	0.19
7	28,765	29,228	2,275	2,629	1	H <sub>2</sub> SiF <sub>6</sub>	4,930	7,205	7,559	0.25	0.26
8	20,500	16,343	1,272	1,470	1	Na <sub>2</sub> SiF <sub>6</sub>	3,696	4,968	5,166	0.24	0.25
9	20,000	15,481	1,205	1,392	1	Na <sub>2</sub> SiF <sub>6</sub>	3,491	4,696	4,883	0.23	0.24
10	13,800	26,564	2,067	2,389	2	NaF	6,500	8,567	8,889	0.62	0.64
11	5,280	14,250	1,109	1,282	1	Na <sub>2</sub> SiF <sub>6</sub>	2,779	3,888	4,061	0.74	0.77
12	2,800	13,598	1,058	1,223	6	H <sub>2</sub> SiF <sub>6</sub>	1,718	2,776	2,941	0.99	1.05
13	2,000	9,367	729	842	1	NaF	1,050	1,779	1,892	0.89	0.95
14	1,300	9,108	709	819	1	NaF	567	1,276	1,386	0.98	1.07
15	800	7,503	584	675	1	H <sub>2</sub> SiF <sub>6</sub>	312	896	987	1.12	1.23
16	498	4,637	361	417	1	H <sub>2</sub> SiF <sub>6</sub>	234	595	651	1.19	1.31
										Mean=\$0.52	\$0.55
										Median=0.25	0.26
										Range=0.12-1.19	0.13-1.31

NaF=granular sodium fluoride,  
H<sub>2</sub>SiF<sub>6</sub>=hydrofluosilicic acid,  
Na<sub>2</sub>SiF<sub>6</sub>=sodium silicofluoride.

\*Estimated equipment replacement cost and installation. †Annualized at 2% and 4% over 15 years. \*\*Cost of chemical, maintenance, and repair.

capital expenditures were estimated using equipment replacement costs in 1988 dollars. Capital costs annualized at 2 percent and 4 percent over a period of 15 years were added to the cost of chemicals, maintenance and repair, testing, personnel, and "other" costs to obtain the annual cost per student. Operational and equipment costs used in Tables 13 and 14 were provided by fluoridation engineers and technicians from each program, and in some instances by state dental directors.

Sealant programs can be conducted in a variety of ways depending on the availability of space, personnel, and characteristics of the particular state program. Therefore, sealants services can be provided as part of an existing clinical program, initiated as a distinct program, or offered through referral programs with services provided by private practitioners. For these reasons, the calculation of annual costs in Tables 15-16 required a different set of assumptions for each type of service delivery. For sealant programs conducted using portable units (set up within schools), initial equipment costs were annualized at 2 percent and 4 percent over a period of ten years. Some programs used dental vans to transport portable equipment to and from schools (unlike dental trailers, which are larger vehicles equipped in most instances for preventive as well as treatment services). Capital costs for the purchase of such vans were also amortized at 2 percent and 4 percent rates of discount, but over a five-year period.

For workshop use, all cost data are presented in ranges. This is done because of the differing approaches to cost derivation used by those providing the information, and because all figures are empirical without allowance for

program inefficiencies. These ranges were provided as a basis for the estimation of true costs and for sensitivity analysis by the work groups.

**Community Water Fluoridation.** Costs of community water fluoridation were obtained from selected communities in the US with systems that have been in operation from one to 14 years. Although these cost figures offer some geographic diversity, the selection of a particular system usually depended on the availability and quality of existing records. A total of 57 water systems throughout the US were surveyed: operators from 42 systems were contacted by telephone, and data for 15 other systems were provided by state dental divisions. Of these 57 cities and communities, 19 returned incomplete reports, six did not respond, and three were no longer fluoridating water supplies. The towns that discontinued fluoridation reported using new wells with natural fluoride levels of 0.3 ppm to 0.5 ppm. The most complete and detailed records from 16 water plants were selected from the remaining 29 locations to provide an adequate array of systems for the purposes of the workshop. They are presented in Tables 8-9.

Throughout the process of data collection from the various communities, equipment costs were readily available for recently installed and small fluoridation systems, but such information was often difficult to obtain from larger and older installations. On the other hand, maintenance, repair, and chemical costs were obtained from all communities in detail. For these reasons, the annual costs of fluoridation were also estimated using replacement costs for existing equipment as shown in Table 9. These capital costs include equipment, engineer-

TABLE 10  
Direct Annual Costs of Fluoride Supplement Programs in the US (in 1988 US\$)

State	No. Schools	No. Children	Age	Type & Dosage	Personnel Costs/Year	Materials & Supplies/Year	Other Costs/Year	Total Costs/Year	Costs/Child/Year
1	7	935	6-12	NaF (1 mg)	458	370		828	0.89
2	5*	657	4-5	NaF (1 mg)	NA†	756		756	1.15
3	49	10,751	5-14	NaF (1 mg)	17,264	5,805	1,200 <sup>a</sup>	24,269	2.26
4	12	3,000	5-12	NaF (0.5 mg)	5,278	2,000	1,500 <sup>b</sup>	8,778	2.93
5	—	9,721	4-5	NaF (1 mg) Tabs or drops	39,290	12,000	1,200 <sup>c</sup>	52,490	5.40
All								Mean=\$2.53 Median=2.26 Range=0.89-5.40	

\*Head Start programs affiliated with community health centers.

<sup>a</sup>=Travel; <sup>b</sup>=printing, clerical; <sup>c</sup>=postage.

Direct annual personnel costs:

State 1: 1 hygienist @ \$22,882/year (2% time), benefits included.

State 2: none reported; program is conducted by Head Start staff.

State 3: 2 hygienists @ \$17,264/year (50% time), no benefits.

State 4: 2 hygienists @ \$13.50/hour x 195.5 hours, no benefits.

State 5: 1 full-time coordinator @ \$36,000/year; 1 program director @ \$47,000/year (7% time), fringe benefits included.

**TABLE 11**  
**Direct Annual Costs of Fluoride Mouthrinse (0.2% Weekly NaF) Programs in the US (in 1988 US\$)**

State	No. Schools	No. Children	Age or Grade	Personnel Costs/Year*	Materials & Supplies/Year	Other Costs/Year	Total Costs/Year	Costs/Child/Year
1	477	88,640	Gr. K-6	17,461	28,365		45,826	0.52
2	300	130,000	K-8	26,875	90,000		116,875	0.90
3	325	76,793	6-11 yrs	36,600	45,910		82,510	1.07
4	398	180,462	Gr. K-8	50,136	164,220		214,356	1.19
5	263	124,659	Gr. K-6	8,000	152,084		160,084	1.28
6	60	9,840	5-12 yrs	8,750	4,000		12,750	1.30
7	56	13,000	K-6	6,999	8,500	1,500 <sup>a</sup>	16,999	1.31
8	851	233,588	Gr. 1-6	69,500	245,700	46,800 <sup>b</sup>	362,000	1.55
9	136	36,155	Gr. K-6	37,125	12,405	9,960 <sup>c</sup>	59,490	1.65
10	137	26,907	7-14 yrs	15,400	29,060	1,200 <sup>d</sup>	45,660	1.70
11	1,537	358,263	Gr. K-8	467,458	170,900		638,358	1.78
All							Mean=\$1.30 Median=1.30 Range=0.52-1.78	

\*See Table 12.

<sup>a</sup>=printing costs; <sup>b</sup>=\$.20 per child, health department administrative costs; <sup>c</sup>=communications, travel, rent, and utilities; <sup>d</sup>=travel.

**TABLE 12**  
**Direct Annual Personnel Costs for Fluoride Mouthrinse Programs in the US (in 1988 US\$)**

	State 1	State 2	State 3	State 4	State 5	State 6	State 7	State 8	State 9	State 10	State 11
<b>Salaried</b>											
# employed	4	1	1	8	1	2	None	4	1	NA*	None
Salaries	\$49,250	\$26,875	\$32,000	\$25,068	\$24,024	\$16,400		\$47,000	\$31,778		
(% effort)	10	100	100	25	33.3	25		33	25		
	\$18,927					\$18,600		\$24,000			
	33					25		100			
	\$11,545							\$20,000			
	20							75			
	\$9,905							\$20,000			
	20							75			
Subtotal	\$15,461	\$26,875	\$32,000	\$50,136	\$8,000	\$8,750	—	\$69,500	\$7,945	—	—
<b>Contract</b>											
# employed	3		1				5		16		25†
Wages	NA*		\$15/hr				\$13.50/hr		\$14.59/hr		\$8.90– \$17.50/hr
# hours			306.7				103.69		125.0		
Subtotal	\$2,000	—	\$4,600	—	—	—	\$6,999	—	\$29,180	—	—
<b>TOTAL</b>	\$17,461	\$26,875	\$36,600	\$50,136	\$8,000	\$8,750	\$6,999	\$69,500	\$37,125	\$15,400	\$467,458

\*Information not available.

†Includes 1 coordinator, 5 field supervisors, 17 field consultants, 1 inventory specialist, and 1 secretary.

ing, and installation costs. The cost for engineering was estimated as 15 percent of the cost for new equipment; installation of equipment was calculated as twice the equipment costs, excluding the cost of containment for large systems (Reeves TG, Centers for Disease Control,

Atlanta; Magnant ML, Iowa Department of Health, Iowa City. Both personal communications, Feb 1989).

It should be noted that the total costs of fluoridation in a given community will vary greatly depending not only on the water plant's capacity and population served, but



**TABLE 13**  
**Direct Costs of School Water Fluoridation Programs in the US, Based on Equipment Replacement Costs (in 1988 US\$)**

State	No. Schools	No. Students	Initial Capital Costs ('88\$)*	Capital Costs/Year†		Costs of Chemical /Year	Oper. Costs/Year**	Personnel Costs/Year‡	Other Costs	Cost/Student/Year	
				(2%)	(4%)					(2%)	(4%)
1	4	2,500	8,100	630	729	300	400	200	500 <sup>a</sup>	0.81	0.85
2	103	28,896	154,500***	12,024	13,896	2,100	10,300	76,400		3.49	3.55
3	89	37,000	195,800	15,238	17,610	4,450	8,900	95,408	26,700 <sup>b</sup>	4.07	4.14
4††	134	48,500	241,200	18,772	21,694	16,000	NA	175,970	1,500 <sup>c</sup>	4.38	4.44
5	14†††	3,300	24,500	1,907	2,204	896	1,400	10,710	400 <sup>d</sup>	4.64	4.73
6††	28	4,880	63,280	4,925	5,691	2,500	NA	40,000		9.72	9.88
All										Mean=\$4.52	\$4.60
										Median=4.23	4.29
										Range=0.81-9.72	0.85-9.88

\*Includes equipment replacement cost, testing equipment, and installation.

†Annualized capital cost at 2% and 4% over 15 years.

\*\*Cost of lab testing and routine maintenance and repair.

‡See Table 14.

\*\*\*No installation costs included; state employees install equipment.

††Source: Dr. R. Gerlach (1989).

†††Program discontinued Dec. 1988.

<sup>a</sup>=travel \$350/year, postage \$150/year; <sup>b</sup>=travel, repair parts, \$300/school/year; <sup>c</sup>=all other costs; <sup>d</sup>=secretarial costs \$400/year.

**TABLE 14**  
**Direct Annual Personnel Costs for School Water Fluoridation Programs in the US (in 1988 US\$)**

State	Type of Personnel	Cost (\$)	Total Cost/Year
State 1	Honorarium for program supervisor	200	200
State 2	2 full-time program representatives @ \$31,000/year	62,000	
	1 technician @ \$14,400/year	14,400	76,400
State 3	4 fluoride specialists and 1 support person \$922/school/year	82,058	
	1 school employee @ \$5.00/hour x 30 hours/year x 89 schools	13,350	95,408
State 4	1 engineer @ \$45,000/year (10% time)	4,500	
	6 technicians, appr. @ \$22,048/year (70% time)	92,603	
	1 clerk \$203.08/year	203	
	1 lab employee @ \$20,000/year	20,000	
	Administrative costs \$58,664/year	58,664	175,970
State 5	1 fluoridation technician @ \$765/school/year	10,710	10,710
State 6	1 engineer @ \$21,000/year (50% time)	10,500	
	1 technician @ \$22,000/year	22,000	
	Clerical \$4,000/year	4,000	
	Administrative costs \$3,500/year	3,500	40,000

also on the type of installation, type of chemical, number of injection points, and natural level of fluoride. For example, communities #12 and #13 serve approximately the same size population, yet the system serving 2,800 residents costs almost twice as much in annual capital costs (Table 9). This can be explained not only in terms of the higher installation cost for its equipment, but also in

that the system has six injection sites compared to only one for the smaller town. It is also worth noting that the cost of chemicals in these communities ranged from 16 cents/lb for bulk purchases of hydrofluosilicic acid to 98 cents/lb for sodium fluoride.

**Fluoride Supplements.** Seven out of 17 states surveyed had dietary fluoride supplement programs in ef-

**TABLE 15**  
**Direct Annual Costs of Sealant Programs in the US (in 1988 US\$)**

State	No. Students	Age or Grade	Type of Sealant	Personnel Costs/Year*	Materials & Supplies/Year	Equipment Costs/Year†		Other Costs/Year	Total Direct Costs/Year		Cost/Student/Year (US\$)	
						(2%)	(4%)		(2%)	(4%)	(2%)	(4%)
1	1,450	7-12	Light-cured	14,862	2,790	445	493	800 <sup>a</sup>	18,897	18,945	13.03	13.07
2	19,084	Gr. 2,3,6,7	Self-cured	210,100	31,400	11,873	12,684	19,800 <sup>b</sup>	273,173	273,984	14.31	14.36
3	1,603	Gr. K-6	Light-cured	31,283	4,800	1,500 <sup>c</sup>	1,500 <sup>c</sup>	300 <sup>d</sup>	37,883	37,883	23.63	23.63
4A	3,801	Gr. 2,3,6,7	Self-cured	78,944	6,890 <sup>**</sup>	3,768	4,173	695 <sup>e</sup>	90,297	90,702	23.76	23.86
4B	3,392	Gr. 2,3,6,7	Self-cured	66,946	9,103	1,686	1,867	3,167 <sup>f</sup>	80,902	81,083	23.85	23.90
5	1,001	Gr. 2,6	Light-cured	24,112	2,410	1,232	1,365	506 <sup>g</sup>	28,260	28,393	28.23	28.37
All											Mean=\$21.14	21.20
											Median=23.70	23.75
											Range=13.03-28.23	13.07-28.37

\*See Table 16.

†Cost of dental vans are annualized at 2% and 4% over 5 years; portable equipment annualized at same rate over 10 years.

\*\*Includes 100 kits of sealant materials donated by Johnson & Johnson @ \$45.95 each.

<sup>a</sup>=Maintenance and repair \$200, travel \$600.

<sup>b</sup>=Travel \$18,700, maintenance/repair \$1,100.

<sup>c</sup>=Leased dental van \$1,500.

<sup>d</sup>=Maintenance and repairs \$200, printing costs \$100.

<sup>e</sup>=Travel \$495, maintenance and repair \$200.

<sup>f</sup>=Maintenance and repair \$200, printing \$1,180, and travel \$1,787.

<sup>g</sup>=\$174 m/repair, \$332 promotional materials.

**TABLE 16**  
**Direct Annual Personnel Costs of Sealant Programs in the US, 1988 (in 1988 US\$)**

State	Type of Personnel	Cost	Total Cost/Year
State 1	Not available	\$14,862	\$14,862
State 2	63% of personnel cost for entire program, includes: 2 dentists, 6 hygienists, and 8 assistants	210,000	210,000
State 3	2 hygienists, 792 hours @ \$10/hour	15,840	
	2 assistants, 720 hours @ \$7/hour	10,080	
	1 dentist, 298 hours @ \$18/hour	5,364	31,284
State 4A	1 coordinator, 60% time	NA	
	3 hygienists @ \$10.85/hour plus benefits	NA	
	3 assistants @ \$7.01/hour plus benefits	NA	78,944
State 4B	1 program coordinator, 30% time	12,609	
	2 hygienists, 10% time, 12 months/year	30,402	
	2 assistants, 28 hours/week, 9 months/year	16,565	
	1 secretary, 10% time, 12 months/year	2,581	
	1 dentist, \$25/hour plus travel	4,789	66,946
State 5	1 program coordinator, 50% time	11,250	
	2 hygienists, 298.35 hours @ \$16/hour	9,547	
	2 assistants, 185.4 hours @ \$7/hour	2,595	
	1 dentist, 45 hours @ \$16/hour	720	24,112

**TABLE 17**  
**Direct Costs of Applying APF Gel (1.23%) Annually in the US (in 1988 US \$)**

Source*	Cost of Materials (US \$)					Personnel: Average Cost/Hour**
	Amount/ Bottle (oz)	Cost/ Bottle	Cost of Gel/Ap- plication†	Cost of Trays/Ap- plication	Total Material Cost/ Application	
Hoyt Labs Luride®	16	10.36	0.12	0.28 <sup>a</sup>	0.40	Dental assistant \$6.99/hour
Premier Fluorident®	16	16.50	0.18			Clinical services hygienist \$11.34/hour
J&J Nupro APF	16	11.80	0.13	0.39 <sup>b</sup>	0.52	Public health hygienist \$15.50 hour
Oral B Checkmate	16	20.95	0.23	0.43 <sup>c</sup>	0.66	Dentist \$29.41/hour

\*Prices quoted by manufacturers, shipping included.

†Based on 91 applications per 16-oz bottle (5 grams per application).

\*\*Source: Survey of Dental Public Health Salaries, Jan 30, 1989. Dr. J. Alderman, Office of Dental Health, Georgia Department of Human Resources, Atlanta.

<sup>a</sup>=Based on \$14.00 per box of 50 trays (dual or hinged gel trays).

<sup>b</sup>=Based on \$11.63 per box of 30 trays (dual or hinged gel trays).

<sup>c</sup>=Based on \$21.34 per box of 50 trays (dual or hinged gel trays).

**TABLE 18**  
**Annual Caries Increment of Children, Adults, and Elderly  
 in the US, 1978-88, According to Age**

Age	Annual Caries Increments		
	Mean	Median	Range
5-17*	0.8	0.8	0.5-1.1
5-17†	1.4	1.2	0.8-2.6
18-44	1.1	1.1	0.7-1.6
45-64	1.5	1.5	1.2-1.9
65+	1.7	1.6	1.1-2.4

\*Fluoridated communities.

†Fluoride-deficient communities.

fect. Two were operated by Head Start programs and no cost data were available from them. Costs for the remaining five programs, and details of the number of employees, type of personnel, and their salaries or wage rates are presented in Table 10. As with community water fluoridation programs, differences in costs are obvious among the various locations. Inspection of these data reveals that programs vary in terms of the number, type, and salary of personnel, as well as in their involvement of community volunteers, teachers, and other school personnel.

All programs reported using school volunteers or teachers to distribute fluoride tablets, although clearly they did not depend on such personnel equally. Personnel costs tended to fluctuate greatly from no reported cost (state #2) up to 75 percent of total program costs (state #5). None of the programs shown in Table 10 attributed as personnel costs the time required from teachers and volunteers, nor did any account for promotional costs.

**TABLE 19**  
**Direct Costs of Caries Prevention Programs in the US  
 (in 1988 \$)**

Program	Annual Cost per Person		
	Mean	Median	Range
Water fluoridation	0.54	0.26	0.12-1.31
Fluoride supplements	2.53	2.26	0.89-5.40
Fluoride mouthrinses	1.30	1.30	0.52-1.78
School fluoridation	4.56	4.26	0.81-9.88
Sealants	21.17	23.73	13.03-28.37

Annual costs per student were calculated based on the number of children served by the programs. However, the reported number of students served by these fluoride supplement programs is an estimate of the actual number of participants. None of the states contacted measured participation rates, thus the annual cost per student is the cost of the supplement program for the "intended" population, rather than the number of students reached.

**Fluoride Mouthrinses.** Direct annual costs of fluoride mouthrinse programs in the US are shown in Tables 11-12. From a total of 17 states contacted, 13 operated such programs, and data were obtained from 11 of them. As with fluoride supplement programs, this type of preventive measure is conducted in schools and school personnel are frequently trained to carry out the weekly rinse activities. Not all programs, however, relied on school personnel to the same extent, nor did they hire similar numbers of people. For example, state #5 calculated personnel costs based on one-third of the time of one program coordinator, who was paid \$24,069 annually. Thus, the total personnel cost reported represents

approximately 5 percent of the total program costs. By contrast, the program in state #11 functions with a number of field workers, consultants, clerical help, and a coordinator. For this program, a large part of the total direct cost (73%) was due to personnel costs.

Cost of materials and supplies for the rinse programs can vary depending on how materials are dispensed. The least costly method is the use of pumps, which can be sterilized and reused several times, or the use of paper cups to distribute the rinsing solution to students. Pre-mixed fluoride rinses are also available that do not require separate paper products for dispensing the solution, but are significantly higher in cost. The range in material costs per child can be demonstrated by examining data from programs in states #2 and #5. Although the target population for these programs is somewhat similar, state #2 spent 69 cents/child/year in rinse products and paper supplies, while state #5 spent \$1.22/child/year using pre-mixed rinses.

Only direct costs are summarized in Table 11, namely the cost of personnel, materials, supplies, and, in a few instances, administrative, travel, and printing costs. No costs were included for teachers' and volunteers' time. As noted in the discussion of fluoride supplement programs, the annual cost of fluoride mouthrinse programs per student is based on the intended population, rather than the actual number of students participating in the program. These costs ranged from 52 cents to \$1.78 per child per year.

**School Water Fluoridation.** Relatively few states operate programs of school fluoridation, so data received were naturally limited. From a total of 17 states surveyed, cost data were obtained from three programs currently in operation, and from another program where school fluoridation had been discontinued in 1988. Information for the fifth and sixth programs, one of which is also no longer in operation, were obtained from a recent survey of school water fluoridation in the US (Gerlach R, Division of Dental Health, Vermont Department of Health. Personal communication, Mar 1989). Although a number of other states, notably in the Southwest and Alaska, have programs in effect, most are small installations not likely to be representative of other regions of the country.

Capital costs for all programs listed in Table 13 were based on the replacement cost for existing fluoridation and testing equipment. Installation costs were also included as initial capital expenditures, except for one location (state #2) where state employees install their own fluoridators. The cost per system and cost per installation did not vary greatly among the six programs, ranging from \$1,500 to \$2,200 per unit/school (fluoridator, testing equipment, pump, plumbing), and from \$300 to \$500 per installation per school. In contrast, the cost of chemicals ranged from \$20.30 per school per year to \$119 per school/year. The greatest difference in

program costs can be noted in the number and cost of personnel utilized by the programs, summarized in Table 14.

**Sealants.** Tables 15-16 show the data obtained for a number of sealant programs in operation in the US. Cost information was available from five states; the remaining 11 states surveyed either offered sealants as part of a clinical program, did not have cost data, or had no program. Only two of the six programs listed in Table 15 had initiated sealant activities during 1988 (states #1, #3), all others were ongoing projects implemented during earlier years. Thus, initial equipment costs for programs in states #2, 4A, 4B, and 5 needed to be expressed in 1988 dollars by either adjusting for inflation, or by using new equipment costs. Because the type of equipment being used in these four programs was known, and similar if not identical models are still available from the manufacturers, replacement costs were used. Once annualized, equipment costs were added to personnel, materials, supplies, and other costs to derive the cost per student per year.

One could argue that the cost of a sealant program is not only the cost of placing sealants, but also the cost of examining all students and subsequently treating those eligible for the service. Thus a distinction should be made between the annual cost per student sealed and the cost per student examined. The annual cost, which ranged from \$13.08 to \$28.43 per child/year, represents (with two exceptions, states #4A and 4B) the cost per student sealed, not per student examined. The real cost of a program is therefore likely to be higher when the cost of screening is included.

**Self- and Professionally Applied Gels.** Data could not be located, either in the literature or from program directors for the sixth type of program—that is, self- and professionally applied fluorides. Therefore, the cost of the basic materials of 1.23 percent APF gel and the cost of fluoride gel trays were included in Table 17. Although state practice acts will differ in the type of personnel and supervision required for such programs, minimally one would need the services of hygienists and assistants, and in some instances supervisory dentists. The wage rates of these dental health professionals were included to assist work groups to calculate direct program costs.

**Summary of Findings.** Caries incidence for age groups 5-17, 18-44, 45-64, and 65+ are summarized in Table 18. The data are presented as mean, median, and range of increment/year for use in the workshop. Some of the studies included in this review reported findings as DMFS per year; others used DFS per year or DFS per 100 surfaces at risk. For this reason, the reader is referred to Tables 1-7 for more details. The direct costs of the various caries prevention programs obtained for the workshop are summarized in Table 19. All cost data are presented as reported from dental public health personnel, water plant operators, and fluoridation engineers.

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