Due to the increasing use of the membrane filter in detecting total coliform organisms, there has developed a need for a similar test for fecal coliforms. Personnel at the former Taft Engineering Center developed a medium to detect fecal coliforms with an elevated temperature test by using a membrane filter (MFFCC, Membrane Filter Fecal Coliform Count) (Geldreich, et al., 1965). This procedure, unlike earlier ones, required no prior enrichment period or chemical test. The technique employs an M-FC Broth base medium and an incubation temperature of 44.5°C (± .5°) in a water bath for 24 hours (± 2). After incubation, the blue fecal colonies are counted. Tests on over 3,000 samples from several different types of sources in Ohio confirmed that an average of 93.2 percent of the blue colonies were truly fecal in nature and that 83.9 percent of the nonblue colonies were nonfecal (Table 4) (Geldreich, 1966). Table 3 shows a comparison between the membrane filter and the MPN analysis for fecal coliforms. The overall ratio of MFFCC (referred to as MFC in the table), to MPN for the entire group of samples was 1.04.

TABLE 4

Fecal Coliform Verification of Blue and Cream-Colored Colonies on M-FC Medium*

	Blue Colonies			Cream Colonies		
Source	Total No.	Number Verified As Fecal	Fecal Percent	Total No.	Number Verified As Nonfecal	Nonfecal Percent
Wells	60	53	88.3	9	9	100.0
Lakes	60	57	95.0	64	53	82.8
Creeks	496	456	91.9	114	88	87.2
Rivers	2,222	2,076	93.4	208	176	84.6
Lagoon	43	39	90.7	0	0	0
Sewage	150	143	95.3	65	60	92.3
Total	3,031	2,824	93.2	460	386	83.9

*From Geldreich (1966), Table 9.

COMPARISON OF TOTAL COLIFORMS AND FECAL COLIFORMS

There are many variables present in trying to relate fecal coliforms to total coliforms. These variables include stream flow, precipitation and runoff, characteristics of the runoff area, season of the year, and existence of effluents. The presence of these variables, together with inconsistencies in sampling, make it nearly impossible to correlate fecal and total coliform counts except in a general way. The following information bears this out.

TABLE 5

Coliform and Fecal Coliform Counts at Two Milwaukee (Lake Michigan) Beaches*

Date	BIG BAY BEACH 1964 Membrane Filter Colonies/100 ml Coliform Group	Fecal Coliform Group	Date	KLODE PARK 1964 Membrane Filter Colonies/100 ml Coliform Group	Fecal Colifrom Group
6/15	10	-	6/15	230	-
6/17	900	26	6/17	230	11
6/19	20	< 4	6/19	30	< 4
6/22	100	18	6/22	150	< 4
6/24	700	190	6/24	310	16
6/26	75	26	6/26	20	29
6/29	20	< 4	6/29	< 10	16
7/1	48	12	7/1	15	8
7/6	3,600	110	7/6	650	20
7/8	13,000	100	7/8	860	18
7/10	340	20	7/10	130	30
7/13	430	50	7/13	230	37
7/15	250	< 5	7/15	45	< 5
7/17	52	9	7/17	19	7
7/20	22,000	1,300	7/20	610	45
7/22	1,800	120	7/22	1,600	92
7/24	1,100	140	7/24	370	75
7/27	1,600	88	7/27	980	82
7/29	6,000	180	7/29	2,700	43
7/31	840	83	7/31	350	43
8/3	830	8	8/3	490	7
8/5	2,000	19	8/5	1,400	47
8/7	50	< 5	8/7	95	5
8/10	840	63	8/10	610	< 5
8/12	290	25	8/12	120	20
8/14	880	28	8/14	63	< 5
8/17	50	< 5	8/17	150	5
8/19	710	40	8/19	740	20
8/21	11,000	1,300	8/21	1,800	180
8/24	90	13	8/24	40	< 5
8/26	< 10	10	8/26	5	< 5
8/28	410	57	8/28	160	23
8/31	130	5	8/31	65	5
9/2	110,000	11,000	9/2	750	15
9/4	370	40	9/4	160	< 5
Geometric Avg.	493.9	65.4	Geometric Avg.	186.2	24.5
Arith. Avg.	5,300	520	Arith. Avg.	474.9	37.4
Median	700	27	Median	230	16
Max.	110,000	11,000	Max.	2,700	180
Min.	< 10	< 4	Min.	5	4

*From Ernest (1965), Tables I and II.

A tabulation of total and fecal counts in shown in Table 3. The average fecal count is about 19 percent of the average total count for all stations, but varies from 2 percent to about 76 percent. Total and fecal coliform counts at two Lake Michigan beaches in the Milwaukee area are shown in Tables 5 and 6. The counts in the latter table are those present after an excessive rainfall and high storm sewer flows. The fecal counts are higher than normal at both beaches, but this is not necessarily the case of total counts especially at Big Bay Beach. The large variability in counts is revealed by the differences in geometric and arithmetic average values in Table 5.

Table 7 is a tabulation of data from the Milwaukee sewage treatment plants and also shows ratios of total to fecal counts. The average fecal values are 13.7 percent, 19.8 percent and 24.7 percent of the average total values for each of the stations shown. Coliform counts from different areas during different seasons of the year are shown in Table 8. This table indicates little correlation between the fecal and total counts either for different seasons or different areas. Coliform densities in

TABLE 6

Comparison of Data Following Excessive Rainfall
at Two Milwaukee (Lake Michigan) Beaches*

1964

Date	Big Bay		Klode	
	Coliform Colonies	Fecal Coliform Per 100 ml	Coliform Colonies	Fecal Coliform Per 100 ml
7/20	22,000	1,300	610	45
7/22	1,800	120	1,600	92
7/24	1,100	140	370	75
7/27	1,600	88	980	82
7/29	6,000	180	2,700	43
7/31	840	83	350	43

*From Ernest (1965), Table III.

TABLE 7

Total Membrane Filter Coliform and Membrane Filter Fecal Coliform Concentrations
Milwaukee Jones Island Treatment Plant (All Counts in 1,000's per 100 ml.)*

Month		Total Count on Effluents			Fecal Counts on Effluents			Ratio Total to Fecal		
		Screened Sewage	West Plant	East Plant	Screened Sewage	West Plant	East Plant	Screened Sewage	West Plant	East Plant
1964	Avg.	30,800	1,070	900	5,010	366	221	6.14	2.92	4.08
Aug.	Max.	73,000	3,300	5,000	12,000	1,400	1,100			
	Min.	4,000	140	230	270	33	28			
Sept.	Avg.	51,800	1,800	1,380	6,270	620	560	8.26	2.90	2.46
	Max.	94,000	4,600	2,200	11,000	2,100	1,700			
	Min.	12,000	570	110	1,000	69	100			
Oct.	Avg.	35,600	1,040	1,320	3,450	141	305	10.31	7.37	4.32
	Max.	96,000	3,500	2,900	9,300	510	730			
	Min.	12,000	480	270	660	41	20			
Nov.	Avg.	30,400	1,330	1,090	3,930	108	163	7.73	12.31	6.68
	Max.	88,000	8,800	4,200	8,400	390	660			
	Min.	8,100	120	60	1,600	8	12			
Dec.	Avg.	32,100	780	542	4,070	155	135	7.88	5.03	4.01
	Max.	90,000	2,200	2,600	11,000	430	790			
	Min.	4,900	250	140	700	25	12			
1965	Avg.	15,600	840	354	2,810	324	91	5.55	2.59	3.89
Jan.	Max.	46,000	3,400	1,100	11,000	3,000	250			
	Min.	2,500	140	58	280	39	20			
Feb.	Avg.	12,200	832	343	2,540	188	121	4.80	4.43	2.83
	Max.	27,000	2,300	860	7,200	520	370			
	Min.	1,500	160	100	300	28	27			
Mar.	Avg.	8,190	363	263	1,120	104	71	7.31	3.49	3.70
	Max.	15,000	780	610	2,400	460	200			
	Min.	4,700	140	14	460	30	19			
Apr.	Avg.	8,240	330	273	1,150	69	57	7.17	4.78	4.79
	Max.	26,000	1,000	600	4,100	200	150			
	Min.	2,800	110	60	220	18	16			
May	Avg.	13,200	350	362	1,710	78	99	7.71	4.48	3.66
	Max.	41,000	860	830	4,900	180	180	7.29	5.03	4.04
	Min.	4,700	130	60	400	26	29		(Averages)	

*From Ernest (1965), Table IV.

TABLE 8

Seasonal Variations (Median Values) for Bacterial Discharges in Storm Water and Rain Water from Suburban Areas, Cincinnati, Ohio, and in Agricultural Land Drainage, Coshocton, Ohio*

Source	Date	Total Samples	Season	Total Coliform	Fecal Coliform	Fecal Strep-tococcus	Ratio FC/FS	Percent Fecal Coliform
Wooded hillside	Feb.62 to Dec.64	278						
			Spring	2,400	190	940	0.20	7.9
			Summer	79,000	1,900	27,000	0.70	2.4
			Autumn	180,000	430	13,000	0.03	0.2
			Winter	260	20	950	0.02	7.7
Street-gutters	Jan.62 to Jan.64	177						
			Spring	1,400	230	3,100	0.07	16.4
			Summer	90,000	6,400	150,000	0.04	7.1
			Autumn	290,000	47,000	140,000	0.34	16.2
			Winter	1,600	50	2,200	0.02	3.1
Business district	Apr.62 to Jul.66	294						
			Spring	22,000	2,500	13,000	0.19	11.4
			Summer	172,000	13,000	51,000	0.26	7.6
			Autumn	190,000	40,000	56,000	0.71	21.1
			Winter	46,000	4,300	28,000	0.15	9.4
Rural	Jan.63 to Aug.64	94						
			Spring	4,400	55	3,600	0.02	1.3
			Summer	29,000	2,700	58,000	0.05	9.3
			Autumn	18,000	210	2,100	0.10	1.2
			Winter	58,000	9,000	790,000	0.01	15.5
Rainwater	Jan.65 to Feb.67	49						
			Spring	< 1.0	< 0.3	< 1.0	-	-
			Summer	< 1.0	< 0.7	< 1.0	-	-
			Autumn	< 0.4	< 0.4	< 0.4	-	-
			Winter	< 0.8	< 0.5	< 0.5	-	-

*From Geldreich et al. (1967), Table I.

urban storm water runoff are tabulated in Table 9. An extreme variance in fecal to total values is noted and no correlation is evidenced. Table 10 shows bacteriological and chemical data from a one-day survey of Cedar Creek in eastern Wisconsin, and again correlation is poor.

TABLE 9

Bacterial Densities in Urban Storm Water Runoff[1]

Rainfall-Runoff Event	Indicator Density - Count/100 ml		
	Total Coliform	Fecal Colifrom	Fecal Streptococcus
March 23, 1966**	152,000	3,200	20,000
July 7, 1964*	920,000	27,000	61,000
August 5, 1965*	2,280,000	31,000	48,000
August 19, 1965*	2,670,000	1,210,000	22,000
Sept. 15, 1965**	45,000,000	430,000	42,000
Sept. 22, 1965**	28,000,000	260,000	290,000
Nov. 24, 1964*	270,000	2,650	5,000
Feb. 6, 1964*	250,000	7,400	8,800
Feb. 10, 1966**	23,900	1,050	6,600

*Flow proportional sample
**Grab Sample
[1]From Evans et al. (1967), Table 2.

TABLE 10

Cedar Creek Stream Survey Results*
July 19, 1967

Sample Location	Mileage	5-day BOD mg/l	DO mg/l	MFCC per 100 ml Total	MFCC per 100 ml Fecal
County Trunk Hwy. "NN" below Big Cedar Lake	30.8	1	7.5	1,000	520
Town road bridge, 1 mile below Little Cedar Lake	27.9	2	3.0	2,000	200
Town road bridge in Cedar Creek	25.8	2	7.6	6,000	180
Wis. Hwy. 60 below Mayfield	23.9	2	8.8	15,000	900
Sherman Road bridge 1 mile south of Jackson	21.3	2	8.9	12,000	1,500
Lagoon Outfall Libby, McNeill & Libby	20.5	6/29/67 72 239 8/10/67 164	-	-	-
Wis. Hwy. 60 bridge above Jackson Sewage Treatment Plant	20.0	3	8.9	13,000	1,800
Jackson Sewage Treatment Plant outfall at bridge	20.0	77	-	-	-
County Trunk Hwy. "G" bridge below Jackson	18.5	3	6.4	22,000	1,100
County Trunk Hwy. "M" bridge	15.4	2	7.2	2,000	110
County Trunk Hwy. "Y" bridge	13.1	4	7.8	200	<100
Wis. Hwy. 143 bridge at Horns Corners	11.8	2	8.3	3,000	50
Covered bridge road 3 miles no. of Cedarburg	9.4	3	12.1	1,300	270
County Trunk Hwy. "I" bridge 3-1/2 miles no. of Cedarburg	8.2	2	11.6	4,000	120

TABLE 10 (contd.)

Sample Location	Mileage	5-day BOD mg/l	DO mg/l	MFCC per 100 ml Total	MFCC per 100 ml Fecal
Wis. Hwy. 60 bridge 2 miles no. of Cedarburg	6.3	2	9.9	9,000	1,200
Foot bridge in Cedarburg behind fire dept. bldg.	4.5	2	2.6	4,000	80
Storm Sewer Outfall in Tailrace	4.3	21	-	-	-
County Trunk "T" bridge 1/2 mile above Cedarburg sewage treatment plant	2.0	2	13.2	12,000	130
Cedarburg Sewage Treatment Plant Effluent	1.6	26	-	-	-
Bridge at Hamilton 1/2 mi. below Cedarburg Sewage Treatment Plant at Hamilton	1.2	3	7.8	230,000	3,300
SOUTH BRANCH					
Town Road Bridge 2 miles south of Jackson	0.8	2	6.7	9,000	900

*Kroehn (1967).

Routine sampling at 35 monitoring stations throughout Wisconsin has been conducted for fecal and total coliforms since mid-1965 (Table 11). Through 1968, the data from these samplings have shown very little, if any, trend in total coliform-fecal coliform relationships. Perhaps this inconclusive evidence is due to dissimilar sampling conditions as well as variations in counts. Generally, the fecal counts were much lower than the total coliform counts, the average total count at all monitoring stations for the three and one-half years being 57 times greater than the fecal counts. Average total to fecal ratios over the period in some streams were nearly ten times greater than average ratios in other streams. No correlation of organism populations, either geographically or on the basis of apparent clean (Wolf River) or polluted (Fox River) streams appears to exist. Usually, but not always, the total fecal coliform ratio was higher in the summer than in the winter. The indication here is that perhaps the number of coliforms entering the stream is less in the winter, or that the coliform organism has a faster die-off rate than the fecal coliform in the winter. The large variation in organism counts may be due to substantial changes in organism populations, or, perhaps, to significantly different sampling conditions.

Several sets of samples were collected on the Beaver Dam River below the City of Beaver Dam sewage treatment plant during 1968 (Table 12).

TABLE 11

Total Coliform and Fecal Coliform Counts in Selected Wisconsin Streams*

Date	Rock R. at Afton		Wolf R. at Keshena		Fox R. at Green Bay		Wis. R. at Bridgeport		Chippewa R. at Pepin	
	Total Coliform	Fecal Coliform	Total Coliform	Fecal Coliform	Total Coliform	Fecal Coliform	Total Coliform	Fecal Coliform	Total Coliform	Fecal Coliform
7/65	270		.5	<.1	58		.3	.1	11	.2
8/65	100	39.0	.1	<.1	5		.2	<.1	6	.3
9/65	630	33.0	2.3	.2	16		2.5	<.1	29	.8
10/65	69	7.7	1.1	<.1	14		8.0	.1	42	1.5
11/65	150	8.8	.8	.1	14		6.4	.2	30	2.3
12/65	63	4.5	2.0	.2	46		1.7	<.1	33	1.8
1/66	20	3.8	<.1	<.1	73	19.0	1.1	.3	3.3	1.1
2/66	10	1.9	.1	<.1	35	.5	.2	.1	2.9	1.1
3/66	30	5.1	<.1	<.1	16	3.0	.2	<.1	5	1.1
4/66			.3	<.1	9	<.1	2.3	.1	10	.3
5/66	90	1.9	1.1		4		1.8			
6/66	120	3.8	3.0	<.1	12	<.1	.1	<.1	5.8	<.1
7/66	610	10.0	2.0	<.1	25	1.9	4.0	.2	12	<.1
8/66	310	21.0	1.9	<.1	130	.4	.7	<.1	12	1.0
9/66	280	8.0	.8	<.1	16	1.2	1.7	<.1	15	.2
10/66	37	1.6	1.0	<.1	21	.5	1.9	<.1	130	2.0
11/66	>47	8.0	1.7	<.1	34	.2	6.0	.1	70	1.3
12/66	150	12.0	.6	<.1	71	1.8	120.0	1.3	36	4.1
1/67	75	7.1	1.3	.01	56	1.0	7.0	<.1	35	1.3
2/67	76	12.0	1.2	<.01	32	1.5	.7	.15	36	2.1
3/67	66	2.0	.9	<.01			3.4	.04	31	1.2
4/67	41	2.4	1.3	<.01	16	3.0	1.1	.06	8	
5/67	160	3.1			18	.22	1.8	.07	21	.1
6/67	110	2.0	6.2	.04	28	.4	.9	.02		
7/67	190	4.8	5.0	.07	17	.2	.1	.01	27	.37
8/67	360	4.8					.4	.05	7	.2
9/67	130	2.4	1.9	.01	12	.4	12.0	.15	74	.12
10/67	190	5.6	1.1	>.005	9	.18	3.5	.3	36	.11
11/67	76	4.7	2.7	.015	54	1.8	7.0	.14	71	1.5
12/67	67	7.0	.8	.02	43	3.5	1.8	.03	150	3.5
1/68	320	17.0	.2	<.1	39.0		3.0	.08	34.0	1.8
2/68	68	9.9	.68	.005	50.0	1.9	4.6	.05	30.0	3.2
3/68	38	2.1	4.0	<.1	17.0	.04	2.3	<.1	3.6	.2
4/68	55	2.9	1.6	.005	3.9	.02	2.0	.4	27.0	1.0
5/68	130	2.9	3.3	<.01	11.0	.08	1.8	.07	2.6	.08
6/68	140	2.0	3.4	.01	3.6	.1	3.0	.22	13.0	.09
7/68	120	3.5	.4	.02	1.2	.02	.5	.08	9.0	.2
8/68	17	.4	2.7	.14	2.4	.05	.2	<.01	13.0	.11
9/68	290	21.0	2.2	.01	23.0	1.2	4.0	.16	17.0	.36
10/68	34	.8	2.4	.005	4.9	.08	3.5		18.0	.35
11/68	8.7	.5	.48	.06	11.0	.5	2.8	.10	65.0	3.1
12/68	62	5.9	.38	.005	31.0	1.6	15.0	.10	37.0	2.4

*Partial list of data from 35 monitoring stations, July 1965 to December 1968; (MFCC and MFFCC per 0.1 ml).

TABLE 12

Coliform and Fecal Coliform Counts in Beaver Dam River Below Beaver Dam, Wisconsin Sewage Treatment Plant, Summer 1968*

		Date (1968)								
		Apr. 11	Apr. 16	Apr. 25	May 9	June 6	July 19	Aug. 8	Aug. 22	Aug. 30
Sta. 1 (Avg. of 2)	Total	2.0	190.0	5.5	4.9	20.0	16.5	250.0	85.0	23.0
	Fecal	.25	30.0	.25	.54	.30	.40	4.65	< .1	.35
Sta. 2 ** (STP Eff) Mil. 0.0	Total	21.0	2.7	.69	2.7	1.1	3.4	3.2	11.0	29.0
	Fecal	.20	.06	.06	.30	.15	.05	.26	.21	.76
Sta. 3 (Avg. of 2) Mil. 0.5	Total	320	335	82	90	120	75	405	485	1,400
	Fecal	5.0	22.0	3.0	4.5	4.5	1.8	5.7	5.0	25.5
Sta. 4 Mil. 2.0	Total	180	130	55	140	50	60	270	390	540
	Fecal	4.5	5.0	2.0	8.0	< 1.0	.2	4.7	6.0	15.0
Sta. 5 Mil. 2.8	Total	190	190	56	70	10	90	340	350	480
	Fecal	2.0	2.0	2.0	2.0	1.0	1.8	6.6	5.0	19.0
Sta. 6 Mil. 3.4	Total	150	170	76	110	40	140	710	450	360
	Fecal	1.9	4.9	4.0	2.0	< 1.0	2.1	5.6	5.0	15.0
Sta. 8 Mil. 4.0	Total	90	110	59	70	60	260	360	370	340
	Fecal	1.0	1.9	2.3	2.2	.6	1.6	6.1	3.5	21.0
Sta. 9 Mil. 6.6	Total	25	34	40	43	40	70		210	220
	Fecal	1.0	2.9	2.0	1.1	.6	1.9		2.0	18.0
Sta. 10 Mil. 8.7	Total	16	19	48	26	80	140	300	200	24
	Fecal	6.0	2.1	2.7	.3	.3	2.2	2.2	< 1.0	4.0

* MFCC and MFFCC per 0.1 ml.
** Million per 100 ml.

A good correlation between total and fecal coliforms on any one sampling day did not exist. Generally, the total coliform and fecal coliform counts decreased (or increased) in a like manner downstream, but seldom was the rate uniform. Considering the mean values for the fecal and total counts over the entire sampling period, the fecal count averaged about 2.5 percent of the total count at each station. This was about the same ratio as the counts in the sewage treatment effluent. The average total coliform count for nine samples from the sewage treatment-plant effluent (trickling filter, nondisinfected) was 8,310,000/100 ml while the fecal count averaged 228,000/100 ml. Interference from draw-down activities at Beaver Dam Lake may be the cause of variations in counts on this stream during the sampling period. Although the results of these surveys were inconclusive, they are probably indicative of what further investigations would yield.

As evidenced by the preceding analyses it is apparent that a high correlation between total and fecal coliforms does not exist. Although fecal coliform counts usually represent only a small percentage of total coliform values, occasionally conditions exist when this percentage is much larger. Despite the unrelated results, it is felt that the fecal coliform is a better indicator organism because it is more directly related to sewage contamination than is the total coliform.

WATER QUALITY STANDARDS

The Report of the National Technical Advisory Committee on Water Quality Criteria expressed the opinion "that of the groups or organisms commonly employed in evaluating sanitary conditions in surface waters, fecal coliform is by far the best choice for use in criteria for contact recreation." (Fed. Water Pollution Cont. Admin., 1968). It also stated that localized bacterial standards may be justified if based on sufficient experience, sanitary surveys, or other control and monitoring programs, together with a thorough analysis of the sources of contamination and the degree of threat of pathogens from specific sources.

The best application for fecal coliform detection is in stream pollution studies, wastewater treatment systems, determination of bathing water quality, and other recreational use criteria (Geldreich, 1965). This procedure is not recommended for the examination of untreated water supplies being considered for potable water. Fecal coliforms will be more prominent in recently contaminated waters while insufficiently chlorinated or less recently polluted waters will show a higher percentage of nonfecal coliforms. Use of the fecal coliforms as an indicator does not add greatly to the complexity or expense of sampling and testing water. The report of the Committee on Water Quality Criteria recommended values for recreation activities and also suggested that more research is needed to refine the correlation between fecal coliforms and water-borne disease (Fed. Water Pollution Cont. Admin., 1968).