United States
Environmental Protection
Agency

Region 7
324 East Eleventh St.
Kansas City, Mo. 64106

EPA 907/9-79-002
February, 1979

Surveillance & Analysis Division

EPA

Performance Report

1978 Winter Municipal Wastewater Treatment Facility

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Winter
Municipal Wastewater Treatment Facility
Performance Report

U. S. Environment Protection Agency
Region VII
Surveillance and Analysis Division

Report by
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INTRODUCTION

The Environmental Protection Agency (EPA) has, in response to requirements established by Section 304 (d) (1) of the Federal Water Pollution Act Ammendment of 1972, published information on the degree of biodegradable organic pollutants and suspended sodids to be removed via "secondary" treatment systems (biological). This information proposed that secondary municipal facilities should be designed and operated to remove 85 percent of the waste constituents and should attain an effluent which meets the following limitations:

Secondary Treatment Discharge Levels

	Monthly Average Daily	Weekly Average Daily
Biochemical Oxygen Demand (BOD_5)	30 mg/l	45 mg/l
Non Filterable Solids (NFS)	30 mg/l	45 mg/l

These concentrations, or more stringent, have been widely used to establish limitations for municipal dischargers under the NPDES permit system. Throughout this report the term "secondary" treatment is considered to be interchangable with an effluent quality of 30 mg/l BOD_5 and 30 mg/l NFS.

The Region VII, Surveillance and Analysis Division (SVAN) of the Environmental Protection Agency (EPA) has over the past several years collected a wealth of detailed wastewater treatment facility performance data including analytical results from multiple days of 24-hour composite samples of both influent and effluent samples. Since 1973 Water Section personnel have inspected and sampled approximately 350 secondary wastewater treatment facilities. The resulting data (Table I) from this sample collection effort has resulted in our opinion, one the best available statements of actual performance of existing wastewater facilities now available.

The most recent subset of data collected by SVAN personnel is to provide a performance summary of "secondary" facility types during the winter months with respect to secondary treatment criteria. This report presents and discusses data resulting from the sampling of 70 facilities sampled during the winter of 1978 and supplements a more limited study conducted in 1976.

SCOPE OF CURRENT STUDY

Construction of secondary treatment facilities in the past several years has enjoyed a diversification of facility types placed into operation. The oxidation ditch (OD), rotating biological surface (RBS), activated biological filter (ABF), and covered trickling filter (CTF) have become more common design selections. In order to provide sound engineering decisions, performance verses cost data is critical. This study was designed to provide performance information by field data collection. A similar study was conducted by SVAN personnel during the winter of 1976 for performance data collection. The scope of the 1978 winter study has been diversified to include facility types not included in the 1976 study and enlarged to provide a more representative cross section of facilities within a particular classification. This study was designed to supplement existing data collected by SVAN personnel over the past several years.

Table I
Wastewater Treatment Plant Data Summary (1973-1978)

PLANT TYPE ____________________
FLOW RANGE ____________________

COLUMN 1	2	3	4			5				6			7				8		
FACILITY NAME	STATE	* NUMBER OF PLANTS SAMPLED	INFLUENT BOD5			EFFLUENT BOD5				INFLUENT COD			EFFLUENT COD				INFLUENT NFS		
			AVG	RANGE	S D	AVG	RANGE	S D	REM	AVG	RANGE	S D	AVG	RANGE	S D	%REM	AVG	RANGE	S D
LAGOONS (36 ONE CELL)		86	149			28			81	331			115			65	156		
ACTIVATED SLUDGE		53	201			23			88	469			75			84	211		
TRICKLING FILTERS		140				42			80	466			117			75	218		
OXIDATION DITCH		26	236			17			93	535			66			88	256		
RBS		11	408			54			87	772			126			84	295		
ABF		3	242			31			87	405			100			80	246		
PACKAGE STP'S		10	184			48			74	407			121			70	199		
TOTAL PLANTS		329	202			35			84	396			103			78	226		

COLUMN 1	9				10			11				12			13				14	15	16	17	18	19	20	21	22	23	24
FACILITY NAME	EFFLUENT NFS				INFLUENT NH3 N			EFFLUENT NH3-N				INFLUENT TOTAL P			EFFLUENT TOTAL P				AVG FLOW MGD	% DESIGN FLOW	INDUSTRIAL FLOW	TOTAL INF TOXIC METALS MG/L	O & M PROBLEMS	CHLORINE ADDED	SAMPLING SEASON MONTH	YEAR SAMPLED	TERTIARY PROCESSES		COMMENTS
	AVG	RANGE	S D	REM	AVG	RANGE	S D	AVG	RANGE	S D	%REM	AVG	RANGE	S D	AVG	RANGE	S D	REM											
LAGOONS (36 ONE CELL)	47			70	14.7			5.9			60	9.0			5.0			44											
ACTIVATED SLUDGE	25			88	19.5			10.9			44	11.4			7.6			33											
TRICKLING FILTERS	37			83	21.8			13.4			38	9.8			8.4			14											
OXIDATION DITCH	17			93	22.6			6.4			72	10.7			8.3			22											
RBS	23			92	24.0			13.0			46	18.9			14.9			21											
ABF	17			93	24.7			17.7			28	10.6			9.1			14											
PACKAGE STP'S	50			75	16.5			8.5			48	9.7			7.2			26											
TOTAL PLANTS	31			85	20.5			10.8			48	11.4			8.6			25											

*FACILITIES SAMPLED MORE THAN ONE TIME COUNTED BY THE NUMBER OF SAMPLING PERIODS.

Prepared by J. Hopkins

Since there are only a few oxidation ditch and RBS type facilities in operation the survey was designed so these facilities would be the logistical focal point of secondary plants to be sampled. As in the 1976 winter study, a conscientous effort was made to select facilities which cover the expected range of age, flow volume, operator competence, and industrial waste problems. Table II summarizes the facility types and sizes selected. It is believed that a representative sample of each type of plant was obtained; however, it should be noted that the overall results of the survey do not indicate an overall average effluent quality in Region VII in that this subset of facilities is not representative of the true numerical distribution of the process types in Region VII and of the severe climatic conditions that existed during the monitoring period.

Data from a total of seventy facilities is included in this study. Sampling was accomplished by collecting three consecutive days of 24-hour composite samples of the influent and effluent at each facility during the period of January 25 through March 17, 1978. Analyses performed on each sample included the following:

biochemical oxygen demand (BOD_5)
chemical oxygen demand (COD)
non-filterable solids (NFS)
ammonia concentration (NH_3-N)
total kjeldal nitrogen concentration (TKN-N)
nitrite-nitrate concentration (NO_2-NO_3-N)
total phosphorus (TP)

Table II 1978 Winter Study
Range of Plant Sizes By Plant Type

Design Flow (MGD)	Oxidation Ditch	Rotating Biological Surface	Activated Biological Filter	Uncovered Trickling Filter	Activated Sludge	Aerobic Lagoon	Covered Trickling Filter
< 0.10		1				1	
0.11 to 0.25	3	4		2	1	3	1
0.26 to 1.00	7		2	9	6	3	1
1.01 to 10.0	2	4	1	5	4	4	3
> 10.0				1	1		1
Total	12	9	3	17	12	11	6

In addition influent and effluent temperatures and flow data were collected. Automatic wastewater compositers were utilized for sample collection (composite samplers had a failure rate of approximately seven percent due to freezing or clogged intake lines). Analytical results are presented on the attached summary sheets, according to their respective facility type. Values presented are mean values of composite data.

Facility types sampled were as follows:

1. Oxidation Ditch (OD),
2. Rotating Biological Surface (RBS),
3. Activated Biological Filter (ABF),
4. Uncovered Trickling Filter (UTF),
5. Covered Trickling Filter (CTF),
6. Activated Sludge (AS), and
7. Lagoons (LAG).

DISCUSSION AND RESULTS

A summary of the data from the seventy facilities sampled for the 1978 Winter Study is presented in Table III. The overall average performance of the facilities sampled did not meet "secondary" treatment criteria. On the basis of individual facility types sampled, only the oxidation ditch subset and the activated sludge subset met the defined secondary treatment standards.

A comparison of facility types with respect to the effluent BOD_5 concentration produced is presented in Figure 1. Both the average and the range of performance for facility types is presented. Perhaps a more literal graphical depiction of a facility type's ability to meet secondary

Table III

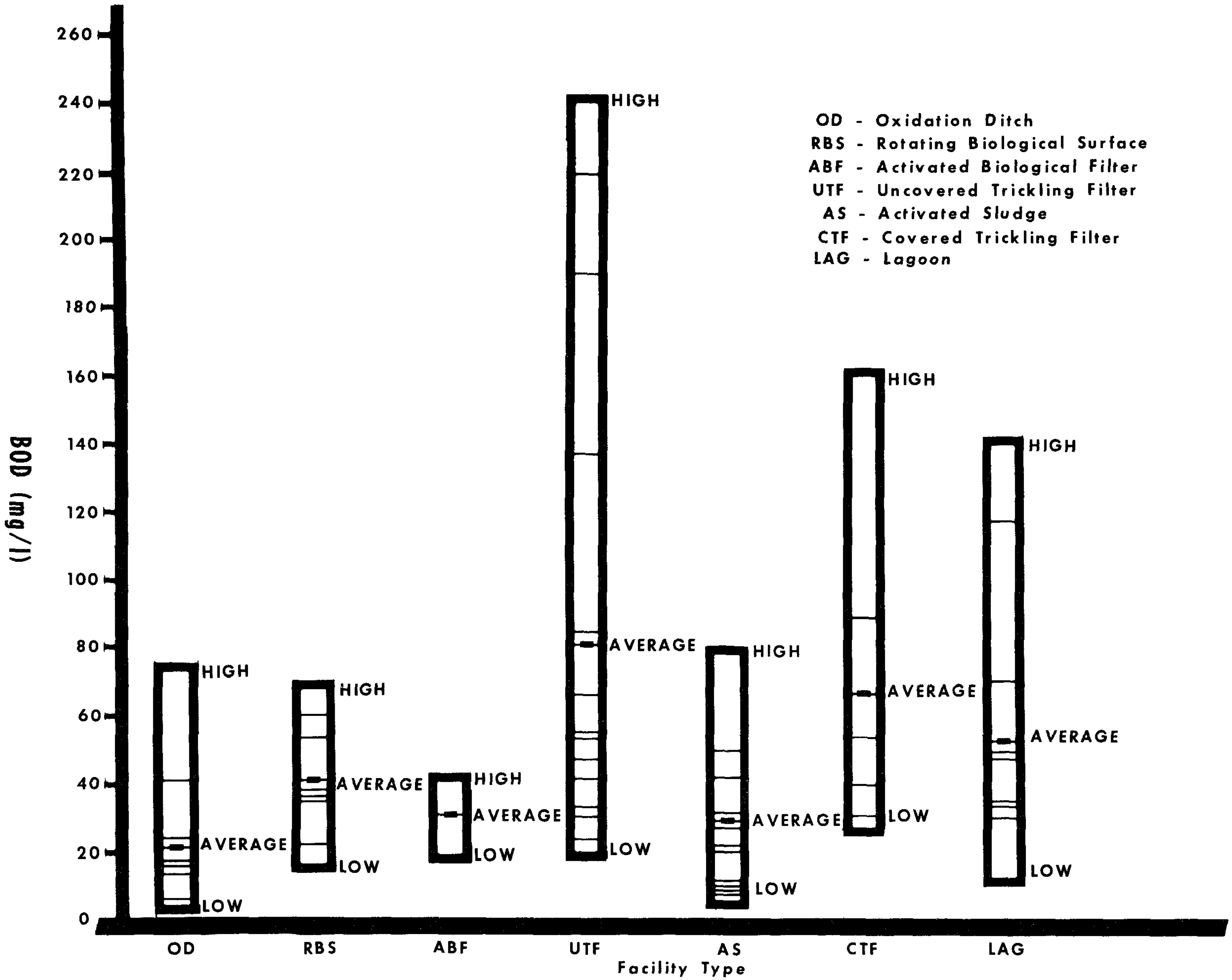
Plant Performance 1978 Winter Study

	Oxidation Ditch Avg Eff Conc	% Removal	Rotating Biological Surface Avg Eff Conc	% Removal	Activated Biological Filter Avg Eff Conc	% Removal	Uncovered Trickling Filter Avg Eff Conc	% Removal	Activated Sludge Avg Eff Conc	% Removal	Lagoons Avg Eff Conc	% Removal
BOD_5 (mg/l)	21± 53	90.0	40± 28	88.7	31± 11	88.0	81± 161	71.4	27± 52	88.8	53± 87	80.6
COD (mg/l)	72± 184	84.0	111± 138	84.9	101± 34	81.1	176± 207	70.2	83± 170	82.9	162± 91	70.4
TSS (mg/l)	23± 138	90.0	22± 16	92.5	18± 6	93.5	59± 174	80.8	24± 105	88.5	44± 78	80.4
NH_3 -N (mg/l)	7.8± 20.0	64.9	14.3± 32.7	38.4	17.9± 8.1	27.2	22.7± 35.3	11.0	15.0± 14.9	30.6	16.1± 13.5	27.1
Eff Temp (°C)	4.5± 7.5	ΔT=5.5	9.7± 6.9	ΔT = 3.2	9.9± 3.3	ΔT=3.5	6.5± 7.8	ΔT=4.4	7.5± 5.5	ΔT= 3.8	1.5± 0.8	ΔT=8.3
Locations Sampled	12		9		3		17		12		11	

Continued on next page

Table III Continued

	Covered Trickling Filter Avg Eff Conc	% Removal	Total Survey Avg Eff Conc	% Removal
BOD_5 (mg/l)	66± 94	80.3	48± 194	82.5
COD (mg/l)	147± 154	75.2	126± 257	77.4
TSS (mg/l)	33± 49	86.7	36± 197	84.9
NH_3-N (mg/l)	22.8± 21.7	26.2	16.5± 41.5	31.3
Eff Temp (°C)	8.3± 6.2	ΔT=2.5	6.2± 10.4	ΔT=4.7
Locations Sampled	6		70	



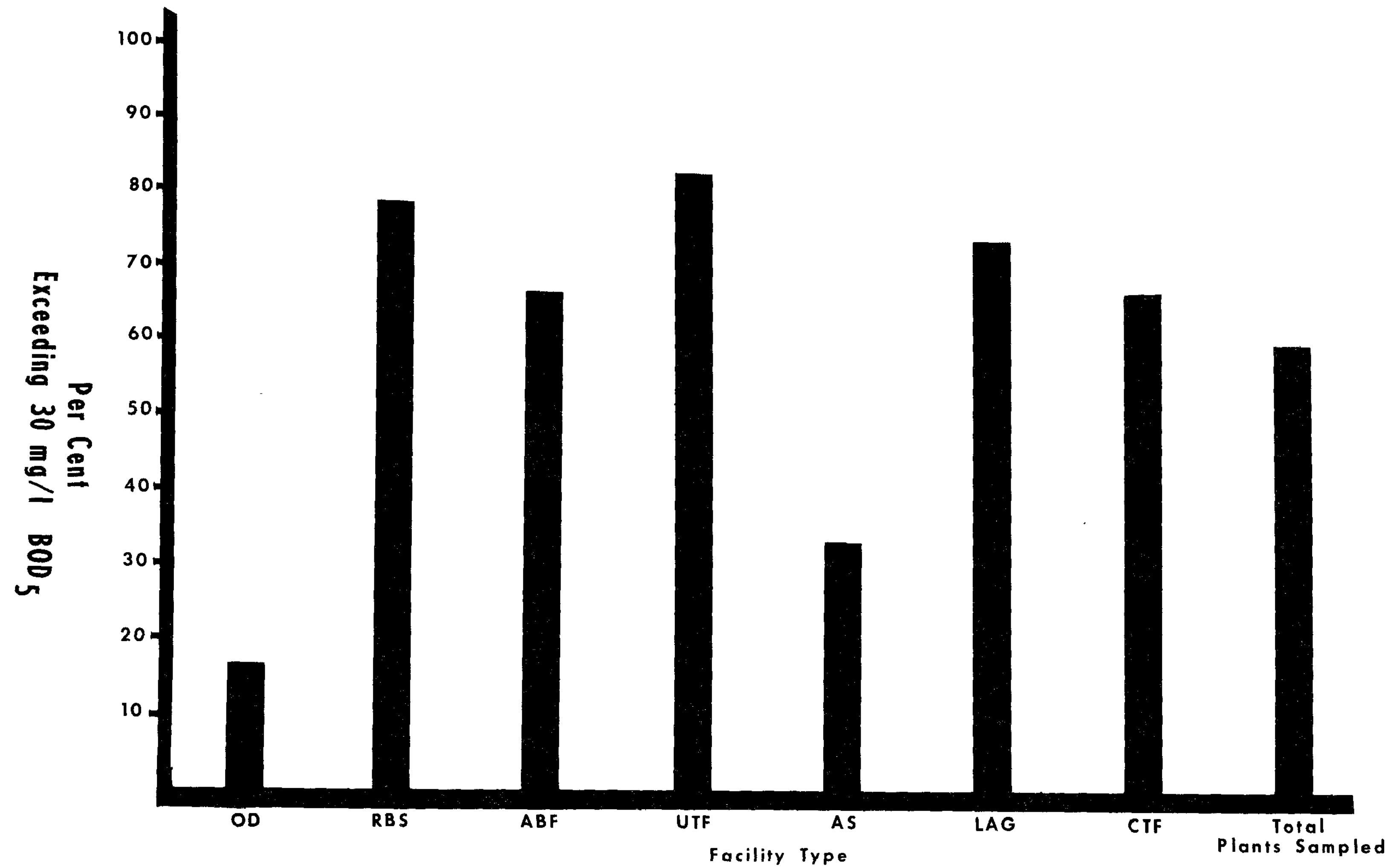
Effluent BOD_5 Concentration

Figure #1

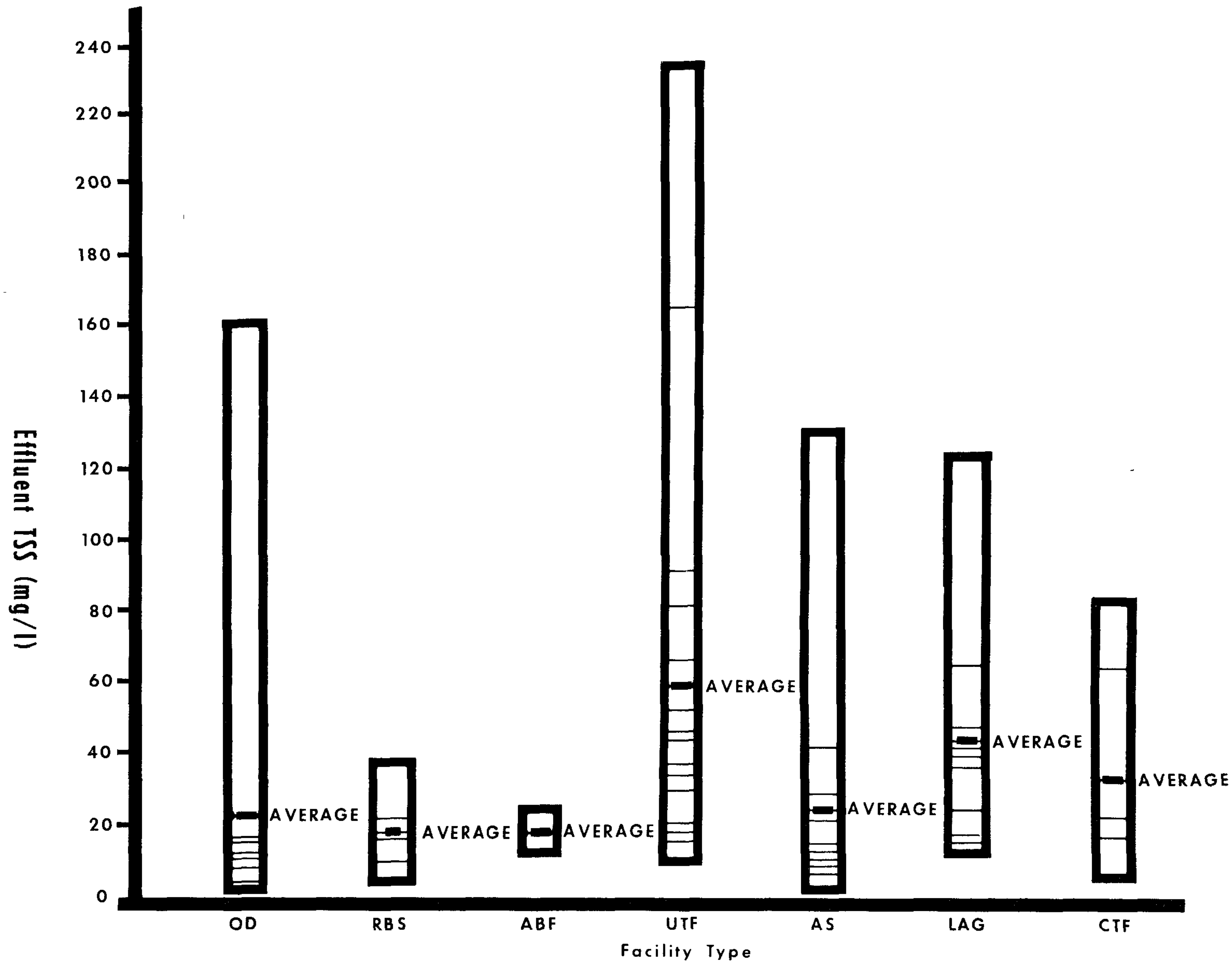
treatment standards is provided in Figure 2. This figure shows quite clearly which treatment types most frequently adhere to secondary standards. Care should be taken, however, not to consider this presentation as an indication of overall effluent quality. From the data collected the oxidation ditch subset and activated sludge subset produced the best effluent BOD_5 concentrations.

Removal of suspended solids is represented by Figure 3. Suspended solids removal, by the treatment systems sampled, fared much better than did BOD_5 removal. Only the trickling filter systems and lagoon facilities did not meet secondary criteria. Figure 4 demonstrates a literal interpretation of a facility type's ability to meet the 30 mg/l NFS limitation. It should be noted that this does not represent overall effluent quality. For example, RBS type facilities had an average effluent NFS concentration of 22 mg/l with thirty-three percent of the facilities exceeding secondary standards. Covered trickling filters (CTF) also had thirty-three percent of the facilities exceed the 30 mg/l NFS limitation, however, the average effluent NFS concentration for CTF's was 33 mg/l.

Figure 5 shows the average ammonia removal (percent removal) of the various treatment system types. This parameter is probably the most sensitive measure of optional performance of secondary treatment systems. It is apparent that a properly designed and operated treatment facility can attain an effluent ammonia concentration of less than 0.5 mg/l

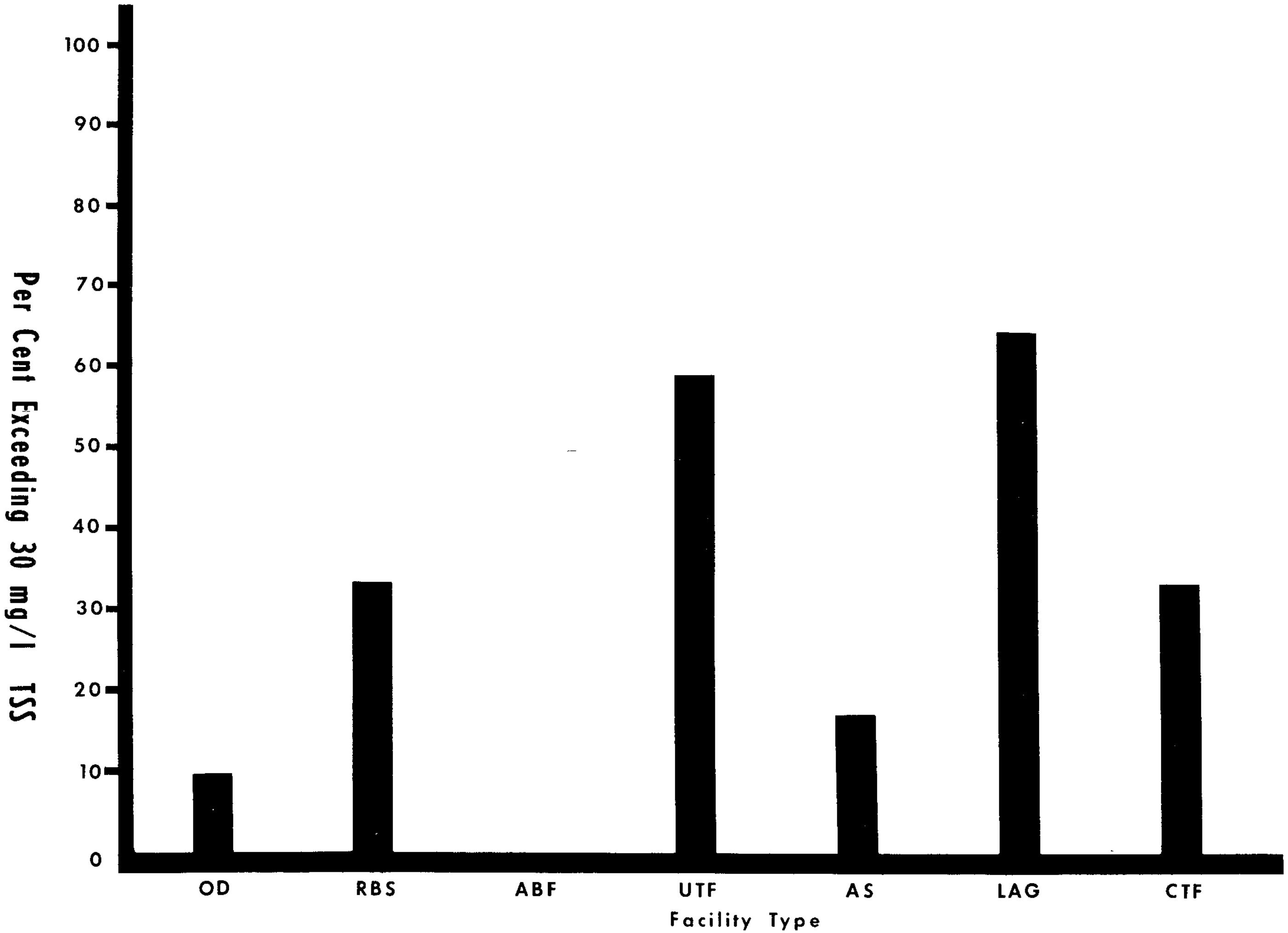


Facilities Failing to Meet 30 mg/l BOD_5
Figure #2



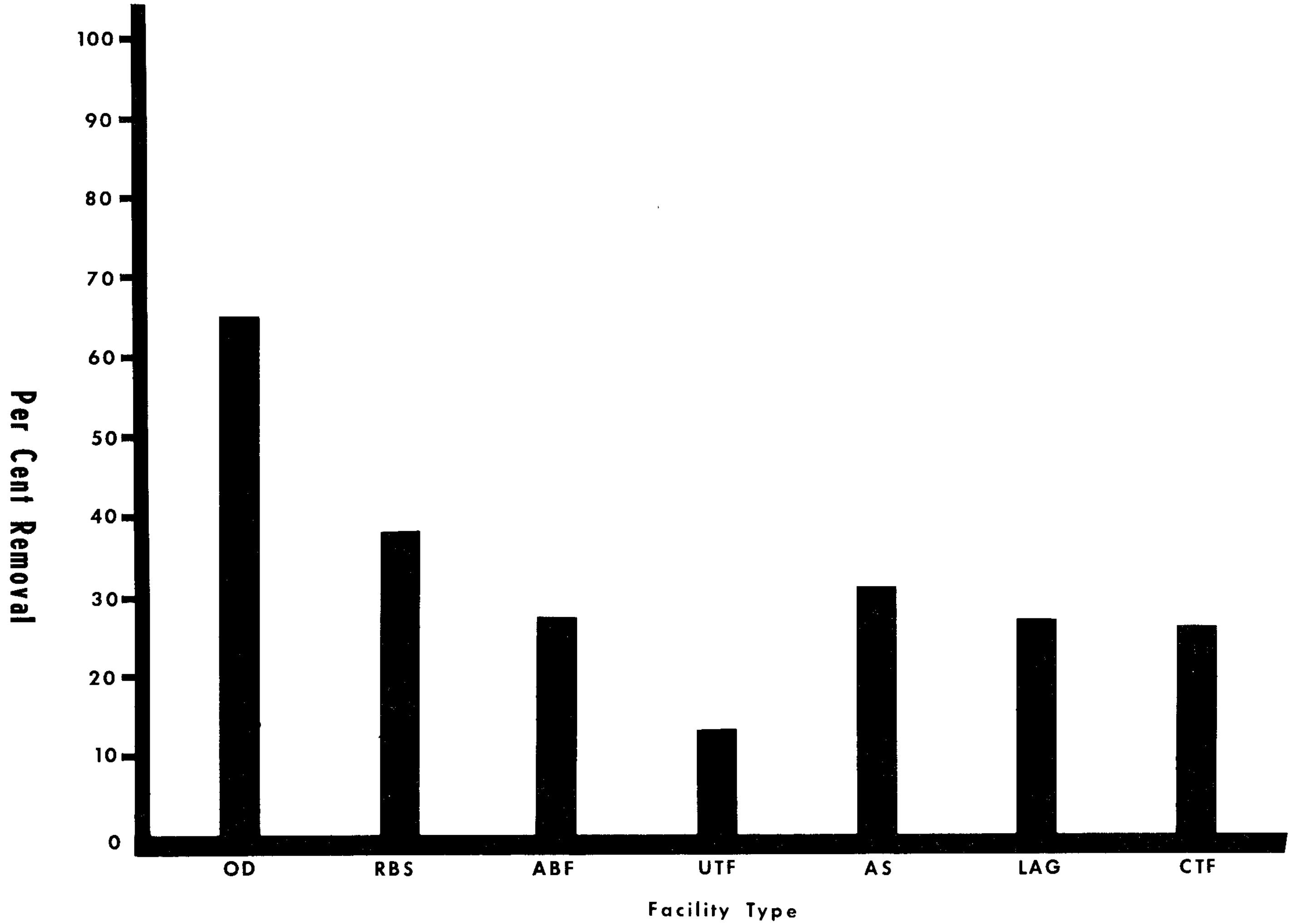
Effluent TSS Concentration

Figure #3



Facilities Failing To Meet 30 mg/l TSS

Figure #4



Amonia Removal

Figure #5

ammonia. During the winter study the oxidation ditch, rotating biological surface and activated sludge facilities attained this effluent ammonia concentration. Nitrification, to this extent, however, occured at only a small percentage of the facilities sampled. Data collected indicates that a small departure from optimal treatment will result in significant increases in effluent ammonia concentrations. The best overall ammonia removal was accomplished by oxidation ditch type facilities followed by RBS and activated sludge systems.

Several additional comments about the survey are offered below:

1. Of the treatment systems sampled, the oxidation ditch seemed to produce the best overall effluent. The oxidation ditch should not, however, be considered the panacea of wastewater treatment. The oxidation ditch, as any other biological system, will fail under adverse conditions, as for example at Laurel, Nebraska. During the sampling period the Laurel effluent varied from 15 mg/l BOD_5 and 9 mg/l NFS to 150 mg/l BOD_5 and 364 mg/l NFS as a result of extreme variations of the influent loading. The influent solids concentration varied from 2490 mg/l to 212 mg/l with a high influent BOD_5 of 750 mg/l and low influent BOD_5 of 180 mg/l during this monitoring period. The performance of the Laurel plant increased the oxidation ditch subset statistics for effluent BOD_5 31 percent, (16 mg/l to 21 mg/l), increased the average effluent NFS concentration by 230 percent (10 to 23 mg/l), and decreased the average ammonia removal by 5.1 percent (64.9 percent from 72.0 percent).

2. Rotating Biological Surfaces produced a comparatively narrow range of effluent qualities. Unfortunately this range was not within secondary standards for BOD_5 criteria. Removal efficiencies of this subset were good; however, this subset also had the highest average influent BOD_5. This resulted in an average effluent BOD_5 of 40 mg/l (88.7 percent removal). Ammonia removal by the RBS subset was second in ranking of the treatment system types sampled with a removals of 38.4 percent.

3. Only three ABF type systems were sampled for the 1978 winter study. In general, the subset performed fairly well. The Fort Dodge treatment facility was hydraulically overloaded, however, having a flow which was 125 percent of the system's design flow.

4. The activated sludge facilities, as a group, performed quite well. The activated sludge subset and the oxidation ditch subset were the only facility types that produced an average effluent quality which was within secondary standards. The poorest performing plant in the subset was hydraulically overloaded.

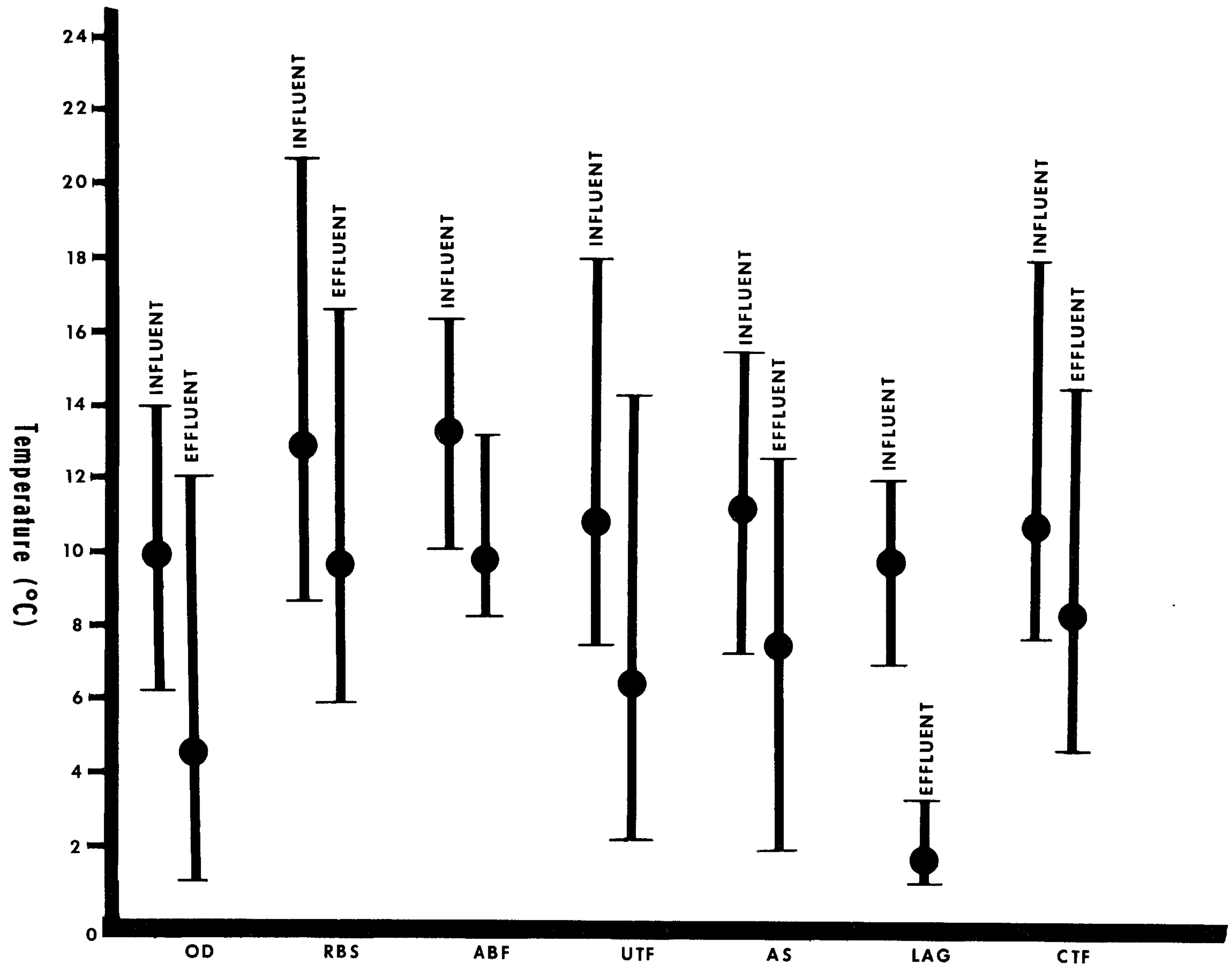
5. The trickling filter subset, both covered and uncovered, performed poorly. Covered trickling filters did out perform uncovered trickling filter in every respect. Trickling filters in general did not meet secondary treatment criteria. Of the twenty-two trickling filter systems sampled, four produced an effluent BOD_5 of 30 mg/l or less. Covering

filters did significantly reduce heat lose (See Figure #6). Covered trickling filters had the lowest ΔT of any of the subsets sampled, yet during this study produced one of the poorest effluents of the facilities sampled.

6. The lagoon subset did not meet secondary standards. Only one of the eleven facilities sampled met 30 mg/l BOD_5 and 30 mg/l TSS limitations. In general, cold weather resulted in increased effluent BOD_5 and decreased TSS concentrations.

CONCLUSIONS

As identified in previous studies, data indicates the major sources for failure to optimize wastewater treatment facilities are hydraulically or organically over loaded plants, poor operation and maintenance (O&M) and/or shock loading as a result of an industrial discharger. Thus, in order to optimize existing systems, an increased emphasis on O&M, flow equalization, and industrial pretreatment would seem to be in order. Also, a need for futher studies in select areas is needed. For example, in the operation of RBS systems very few decisions must be made by operators to control the process, resulting in a narrow range of effluent qualities between system. Of the RBS systems sampled, however, most failed to produce an effluent which met secondary treatment standards. An evaluation of RBS type systems is now being conducted SVAN personnel.



Water Temperature

Figure #6

Table IV
Oxidation Ditch

Plant	Flow MGD Des.	MGD Act	Inf BOD mg/l	Eff BOD mg/l	Inf TSS mg/l	Eff TSS mg/l	Inf COD mg/l	Eff COD mg/l	Inf NH_3 mg/l	Eff NH_3 mg/l	Inf TP mg/l	Eff TP mg/l	Temp °C Inf	°C Eff	Inf TKN mg/l	Eff TKN mg/l	Inf NO_{2-3} mg/l	Eff NO_{2-3}
Bolivar, MO	1.2	0.77	103	2	98	3	239	18	13.8	<0.5	9.6	6.5	10.0	4.7	21.6	0.6	<0.1	13.7
Salem, MO	0.74	0.06	200	12	218	17	433	55	16.2	0.6	8.9	8.0	8.7	1.0	34.7	2.6	0.3	5.1
Seymour, MO	0.255	0.15	450	21	450	11	975	72	36.0	11.8	13.0	7.1	9.0	2.3	51.0	14.0	0.1	17.7
Nixa, MO	0.412	0.095	214	5	235	4	528	32	30.8	<0.4	11.7	9.9	9.6	3.0	41.3	2.5	0.2	30.7
Battle Creek, NE	0.16	0.297	65	21	80	16	141	58	9.1	11.0	4.8	4.0	8.0	3.0	16.3	13.3	0.8	1.3
Nevada, MO	1.75	1.02	148	13	143	8	378	47	16.4	15.6	7.6	5.2	12.0	12.0	23.6	15.6	0.2	<0.1
Randolph, NE	0.324	-	147	17	147	11	325	72	26.3	3.1	8.2	6.7	10.5	2.0	35.0	6.1	0.1	27.7
Laurel, NE	0.20	0.083	400	74	913	161	823	256	26.3	27.8	14.0	13.0	9.0	3.0	46.0	38.3	0.2	0.3
Wymore, NE	0.40	0.3	207	4	205	4	444	56	30.7	0.1	12.0	9.7	14.0	2.7	37.0	1.6	0.3	20.8
Tama, IA	0.495	0.33	200	15	221	8	415	39	19.0	2.8	8.3	6.9	12.8	7.9	34.8	4.0	0.9	2.9
Reinbeck, IA	0.180	0.155	183	40	160	18	343	61	18.0	16.0	15.0	12.0	9.8	6.7	58.3	40.8	0.8	2.2
Corning, IA	0.5	-	220	23	183	12	364	94	24.1	4.2	9.2	8.2	6.3	5.5	33.3	6.2	0.8	12.0
Best Plant	1.20	0.77	103	2	98	3	239	18	13.8	<0.5	9.6	6.5	10.0	4.7	21.6	0.6	<0.1	13.7
Average	0.55		211	21	254	23	451	72	22.2	7.8	10.1	8.5	10.0	4.5	36.1	12.1	0.4	11.2
Worst Plant	0.20	0.08	400	74	913	161	823	256	26.3	27.8	14.0	13.0	9.0	3.0	46.0	38.3	0.2	0.3
Removal %																		
Best Plant				98.1		96.9		92.5		>96.4		32.3	ΔT=	5.3		97.2		-13600.0
Average				90.0		90.9		84.0		64.9		19.8	ΔT=	5.5		66.5		- 2700.0
Worst Plant				81.5		82.4		68.9		-00.1		00.1	ΔT=	6.0		16.7		- 50.0

Table V
Rotating Biological Surface

Plant	Flow MGD Des	Flow MGD Act	Inf BOD mg/l	Eff BOD mg/l	Inf TSS mg/l	Eff TSS mg/l	Inf COD mg/l	Eff COD mg/l	Inf NH_3 mg/l	Eff NH_3 mg/l	Inf TP mg/l	Eff TP mg/l	Temp °C Inf	Temp °C Eff	Inf TKN mg/l	Eff Tkn mg/l	Inf NO_{2-3} mg/l	Eff NO_{2-3} mg/l
Spencer, IA	3.8	0.980	197	15	165	5	455	68	21.3	0.3	9.1	7.7	8.7	6.4	31.0	3.7	0.2	17.4
Hopkinton, IA	0.2	0.187	250	37	187	36	440	88	9.8	2.6	19.0	15.3	17.0	13.0	29.0	7.3	<0.1	11.1
Eagle, NE	0.12	0.04	236	37	341	10	544	83	23.7	14.0	12.7	8.3	10.5	6.5	36.3	14.3	0.5	6.2
Yutan, NE	0.12	-	180	53	141	17	379	103	24.9	22.1	11.3	9.5	12.0	9.3	37.7	25.3	<0.1	1.3
York, NE	2.3	0.96	625	22	422	18	1123	76	35.0	5.4	19.0	11.7	16.2	11.8	84.0	6.9	2.9	30.3
Wood River, NE	0.225	0.12	147	35	117	10	241	53	13.3	10.0	7.1	5.9	10.0	8.5	23.3	10.0	3.4	8.6
Gibbon, NE	1.15	0.55	480	36	492	38	1155	129	26.5	12.0	10.1	6.5	20.7	16.6	67.5	15.0	6.8	13.0
Murray, NE	0.052	0.03	687	68	600	25	1679	249	33.3	47.0	22.3	14.0	11.3	5.9	72.0	55.0	0.5	0.1
Kirksville, MO	5.0	1.46	390	60	180	36	619	151	20.7	15.7	12.7	9.1	9.7	9.0	39.3	23.3	0.1	0.2
Best Plant	3.80	0.98	197	15	165	5	455	68	21.3	0.3	9.1	7.7	8.7	6.4	31.0	3.7	0.2	17.4
Average	1.44	-	355	40	294	22	737	111	23.2	14.3	13.7	9.8	12.9	9.7	46.7	17.9	1.6	9.8
Worst Plant	5.00	1.46	390	60	180	36	619	151	20.7	15.7	12.7	9.1	9.7	9.0	39.3	23.3	0.1	0.2
Removal %																		
Best Plant				92.4		97.0		85.1		98.6		15.4	ΔT=	2.3		88.1		-8600.0
Average				88.7		92.5		84.9		38.4		28.5	ΔT=	3.2		61.7		- 512.5
Worst Plant				84.6		80.0		75.6		24.2		28.3	ΔT=	0.7		40.7		- 200.0

Table VI
Activated Biological Filter

Plant	Flow MGD Des	Flow MGD Act	Inf BOD mg/l	Eff BOD mg/l	Inf TSS mg/l	Eff TSS mg/l	Inf COD mg/l	Eff COD mg/l	Inf NH_3 mg/l	Eff NH_3 mg/l	Inf TP mg/l	Eff TP mg/l	Temp °C Inf	Temp °C Eff	Inf TKN mg/l	Eff TKN mg/l	Inf NO_{2-3} mg/l	Eff NO_{2-3} mg/l
Fort Dodge, IA	4.5	5.64	460	42	404	24	864	145	29.7	26.0	15.3	12.3	16.3	13.2	63.3	34.3	0.2	5.9
Kansas City No 8, KS	0.35	0.26	132	32	152	16	374	101	27.6	25.8	11.1	9.1	13.8	8.3	45.4	32.0	<0.1	<0.1
Mount Vernon, IA	0.5	0.407	181	18	282	15	367	58	16.6	2.0	7.8	6.2	10.1	8.3	26.0	4.4	-	-
Best Plant	0.50	0.41	181	18	282	15	367	58	16.6	2.0	7.8	6.2	10.1	8.3	26.0	4.4	-	-
Average	1.78		258	31	279	18	535	101	24.6	17.9	11.4	9.2	13.4	9.9	44.9	23.6	0.2	3.0
Worst Plant	4.50	5.64	460	42	404	24	864	145	29.7	26.0	15.3	12.3	16.3	13.2	63.3	34.3	0.2	5.9
Removal %																		
Best Plant				90.1		94.7		84.2		88.0		20.5	ΔT=	1.8		83.1		-
Average				88.0		93.5		81.1		27.2		19.3	ΔT=	3.5		47.4		-1400.0
Worst Plant				90.9		94.1		83.2		12.5		19.6	ΔT=	3.1		45.8		-2850.0

Table VII
Uncovered Trickling Filter

Plant	Flow MGD Des	MGD Act	Inf BOD mg/l	Eff BOD mg/l	Inf TSS mg/l	Eff TSS mg/l	Inf COD mg/l	Eff COD mg/l	Inf NH_3 mg/l	Eff NH_3 mg/l	Inf TP mg/l	Eff TP mg/l	Temp °C Inf	°C Eff	Inf TKN mg/l	Eff Tkn mg/l	Inf NO_{2-3} mg/l	Eff NO_{2-3} mg/l
Waterloo, IA	20.35	13.81	472	53	500	37	941	155	28.5	21.0	9.0	8.7	12.7	8.7	-	25.7	0.1	5.6
Grundy Center, IA	0.4	-	387	220	216	165	673	428	22.0	20.7	18.0	12.5	9.8	7.0	38.0	32.3	<0.1	0.2
Perryville, MO	0.9	0.245	280	137	282	81	715	325	29.4	31.9	12.0	12.9	11.6	7.2	40.0	39.1	<0.2	<0.1
Marshall, MO	2.88	3.0	313	18	267	11	646	95	62.0	58.0	16.7	13.0	11.9	3.5	94.7	73.0	<0.1	-
Lexington, NE	1.0	1.25	333	53	428	30	701	125	23.3	15.0	10.4	5.7	12.9	6.4	112.7	20.0	0.1	5.4
Mexico, MO	2.09	1.17	233	41	312	34	621	135	23.7	23.2	11.4	10.5	6.0	4.8	38.0	29.0	0.1	1.7
New Hampton, IA	1.4	0.38	249	185	172	46	576	334	17.7	13.0	9.7	9.1	7.5	2.2	26.0	17.5	0.1	<0.1
Bellevue, IA	0.14	0.25	175	47	176	44	373	108	26.6	25.3	9.7	10.1	7.6	6.3	36.3	28.3	0.3	1.0
West Union, IA	0.44	0.37	241	55	268	20	469	132	23.1	21.2	12.0	8.1	8.0	5.5	43.0	25.0	1.7	1.6
Beatrice, NE	2.5	0.98	117	24	191	30	307	80	17.6	11.0	9.1	4.6	14.5	7.0	25.7	13.9	4.4	14.0
Le Mars, IA	1.0	0.80	552	242	347	91	828	383	25.0	21.8	21.8	18.0	12.4	4.8	42.5	30.6	1.0	0.2
Monett, MO	3.07	1.08	289	33	277	52	593	97	14.8	11.4	11.4	3.1	18.0	14.3	31.3	18.3	0.7	1.4
Stanton, NE	0.16	0.11	413	66	680	66	1054	182	24.7	28.1	21.0	9.5	11.8	5.0	64.3	34.3	0.1	0.3
Atlantic, IA	1.0	0.54	217	30	204	16	377	84	24.7	15.1	10.6	8.8	10.3	7.0	37.0	17.5	<0.1	7.4
Carroll, IA	1.2	0.88	142	41	160	18	308	94	28.5	15.7	15.4	13.3	10.7	6.5	33.5	16.7	1.9	5.0
Iowa City, IA	8.0	6.94	185	84	431	233	396	204	40.3	28.2	9.6	10.0	12.0	9.4	-	-	-	-
Best Plant	2.88	3.0	313	18	267	11	646	95	62.0	58.0	16.7	13.0	11.9	3.5	94.7	73.0	<0.1	-
Average	2.78	2.0	283	81	308	59	591	176	25.5	22.7	12.8	9.8	10.9	6.5	47.4	28.1	0.7	3.1
Worst Plant	0.4	-	387	220	216	165	673	428	22.0	20.7	18.0	12.5	9.8	7.0	38.0	32.3	<0.1	0.2
Removal - %																		
Best Plant				94.2		95.9		85.3		6.5		22.2	ΔT=	8.4		22.9		-
Average				71.4		80.8		70.2		11.0		23.4	ΔT=	4.4		40.7		-342.9
Worst Plant				43.2		23.6		36.4		5.9		30.6	ΔT=	2.8		15.3		-200.0

Table VIII
Activated Sludge

Plant	Flow MGD Des	Flow MGD Act	Inf BOD mg/l Dom	Eff BOD mg/l	Inf TSS mg/l Dom	Eff TSS mg/l	Inf COD mg/l Dom	Eff COD mg/l	Inf NH_3 mg/l Dom	Eff NH_3 mg/l	Inf TP mg/l Dom	Eff TP mg/l	Temp °C	°C Eff	Inf TKN mg/l	Eff TKN mg/l	Inf NO_{2-3} mg/l	Eff NO_{2-3} mg/l
Jesup, IA	0.439	0.3	200	8	241	5	351	33	17.8	11.0	10.1	6.8	10.2	6.5	31.0	12.0	0.2	1.0
Oelwein, IA	1.0	1.12	147	79	131	129	319	253	15.4	12.4	6.9	6.9	8.9	6.9	22.3	22.3	<0.1	<0.1
Marshalltown, IA	10.8	5.9	487	29	321	22	890	67	29.7	25.0	11.3	6.9	15.1	12.6	54.7	30.2	<0.1	0.2
Farmington, MO	1.025	0.191	137	9	155	8	358	36	16.1	15.1	6.9	4.4	15.5	3.0	24.7	5.6	0.1	0.6
Fairbury, NE	1.0	0.7	253	41	233	42	648	148	24.7	27.3	14.3	9.3	12.7	9.7	40.0	34.7	0.5	0.2
Cherokee, IA	2.0	0.865	220	21	229	6	451	38	24.1	*7.4	9.2	6.0	9.5	9.8	38.0	8.6	0.3	9.2
Oskaloosa SW, IA	0.8	0.7	380	21	97	9	505	78	18.5	19.7	11.0	6.6	7.3	5.0	37.0	21.0	0.6	0.3
Ankeny (E), IA	1.2	0.985	295	20	208	13	568	60	26.5	24.3	19.5	8.9	10.2	8.3	48.0	25.0	0.2	0.3
Neligh, NE	0.25	-	177	31	141	15	366	62	24.2	15.0	10.3	8.0	12.0	5.5	24.2	15.0	<0.1	0.6
West Point, NE	0.575	0.37	225	11	162	10	426	73	21.0	0.5	11.0	10.0	10.0	2.0	37.0	3.4	1.6	24.0
Bethany, MO	0.788	0.24	200	49	392	29	477	114	24.9	22.1	10.0	8.1	7.5	5.0	35.0	26.7	0.2	1.9
Mason City, IA	6.5	4.9	170	6	182	3	365	38	17.0	<0.1	18.3	6.6	10.3	9.0	50.3	<1.0	18.3	17.4
Best Plant	6.5	4.9	170	6	182	3	365	38	17.0	<0.1	18.3	6.6	10.3	9.0	50.3	<1.0	18.3	17.4
Average	2.2	-	241	27	208	24	484	83	21.6	15.0	11.5	7.4	11.3	7.5	36.9	17.1	1.8	4.6
Worst Plant	1.0	1.12	147	79	131	129	319	253	15.4	12.4	6.9	6.9	8.9	6.9	22.3	22.3	<0.1	<0.1
Best Plant				96.5		98.4		89.6		>99.4		63.9	ΔT=	1.3		98.0		-155.6
Average				88.8		88.5		82.9		30.6		35.7	ΔT=	3.8		53.7		4.9
Worst Plant				46.3		1.5		20.7		19.5		0.0	ΔT=	2.0		0.0		0.0

Table IX
Covered Trickling Filter

Plant	Flow MGD Des	MGD Act	Inf BOD mg/l	Eff BOD mg/l	Inf TSS mg/l	Eff TSS mg/l	Inf COD mg/l	Eff COD mg/l	Inf NH_3 mg/l	Eff NH_3 mg/l	Inf TP mg/l	Eff TP mg/l	Temp °C Inf	Temp °C Eff	Inf TKN mg/l	Eff TKN mg/l	Inf NO_{2-3} mg/l	Eff NO_{2-3} mg/l
Waverly, IA	1.08	0.693	236	39	234	17	472	98	30.5	17.3	12.7	12.0	9.3	7.7	42.0	21.0	<0.1	1.7
Correctionville, IA	0.168	0.098	93	53	55	6	197	101	21.8	17.2	7.9	8.4	8.1	5.5	28.0	20.8	36.0	2.7
Kearney, NE	3.0	2.66	253	30	325	22	591	92	23.7	19.3	9.4	6.9	13.3	10.5	43.0	21.0	0.1	2.9
Iowa Great Lake S D	2.0	1.93	220	27	159	6	417	104	19.7	12.7	10.8	23.0	7.9	7.0	40.3	24.7	0.3	3.7
Lakeview, IA	0.28	0.14	252	88	197	82	409	187	29.2	25.7	11.1	10.3	7.7	4.7	41.7	31.7	0.7	1.3
Cedar Rapids, IA	28.0	21.56	957	160	508	64	1470	301	60.3	44.5	14.5	6.1	18.0	14.5	91.3	49.5	0.7	0.2
Best Plant	2.0	1.93	220	27	159	6	417	104	19.7	12.7	10.8	23.0	7.9	7.0	40.3	24.7	0.3	3.7
Average	5.75	4.51	335	66	246	33	592	147	30.9	22.8	11.1	11.1	10.8	8.3	47.7	28.1	6.3	2.1
Worst Plant	28.0	21.56	957	160	508	64	1470	301	60.3	44.5	14.5	6.1	18.0	14.5	91.3	49.5	0.7	0.2
Removal - %																		
Best Plant				87.7		96.2		75.1		35.5		-113.0	ΔT=	0.9		38.7		-1133.3
Average				80.3		86.6		75.2		26.2		0.0	ΔT=	2.5		41.1		66.7
Worst Plant				83.3		87.4		79.5		26.1		57.9	ΔT=	3.5		45.8		71.4

Table X
Lagoons

Plant	Flow MGD Des	Flow MGD Act	Inf BOD mg/l	Eff BOD mg/l	Inf TSS mg/l	Eff TSS mg/l	Inf COD mg/l	Eff COD mg/l	Inf NH_3 mg/l	Eff NH_3 mg/l	Inf TP mg/l	Eff TP mg/l	Temp °C Inf	Temp °C Eff	Inf TKN mg/l	Eff TKN mg/l	Inf NO_{2-3} mg/l	Eff NO_{2-3} mg/l
Iola, KS	1.63	1.13	116	12	105	36	294	90	24.7	3.1	6.2	2.2	11.3	0.3	34.0	5.4	<0.1	0.5
California	3.5	0.11	140	13	142	14	325	86	17.7	10.6	8.3	7.6	8.5	1.5	31.0	13.0	<0.1	<0.1
Blue Springs, MO	1.1	-	208	118	194	25	480	247	21.7	29.6	12.5	11.2	12.0	1.5	32.0	<0.1	32.5	<0.1
Frankfort, KS	0.24	0.07	173	35	108	122	348	153	24.0	11.3	9.2	8.9	11.8	1.8	34.0	16.7	<0.1	<0.1
Wakefield, KS	0.08	0.05	267	34	393	47	611	129	19.6	7.5	11.9	4.7	9.3	2.5	38.3	12.9	3.2	0.7
Spring Hill, KS	0.20	0.14	450	30	680	65	1188	131	34.6	10.0	16.4	7.0	10.3	1.3	65.3	16.0	0.1	0.4
Branson, MO	0.81	0.28	732	34	110	39	1140	134	12.0	7.0	12.0	6.6	10.0	1.5	36.0	11.4	0.4	0.2
Maryville, MO	1.81	1.05	190	140	ND	16	354	253	17.0	27.2	8.6	12.4	7.0	1.0	34.0	29.4	0.7	<0.1
Stewartsville, MO	0.8	0.04	300	70	128	42	461	233	26.5	25.7	13.5	11.7	9.3	1.0	45.0	33.3	0.8	<0.1
St. Peters, MO	0.60	0.50	237	49	248	60	486	171	27.6	28.2	15.1	14.4	8.5	3.3	41.8	37.8	<0.1	<0.1
Wathena, KS	0.13	0.032	187	48	138	17	326	155	18.1	16.7	8.8	6.0	9.3	1.0	28.5	21.2	0.3	<0.1
Best Plant	1.63	1.13	116	12	105	36	294	90	24.7	3.1	6.2	2.2	11.3	0.3	34.0	5.4	<0.1	0.5
Average	0.99	0.34	273	53	225	44	547	162	22.1	16.1	11.1	8.4	9.8	1.5	39.2	17.9	3.5	0.2
Worst Plant	1.81	1.05	190	140	ND	16	354	253	17.0	27.2	8.6	12.4	7.0	1.0	34.0	29.4	0.7	<0.1
Removal - %																		
Best Plant				89.7		65.7		69.4		87.4		64.5	ΔT=	11.0		84.1		-400.0
Average				80.6		80.4		70.4		27.1		24.3	ΔT=	8.3		54.3		94.3
Worst Plant				26.3		ND		28.5		-60.0		-44.2	ΔT=	6.0		13.5		85.7