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DRY FEED CHLORINATION OF WASTEWATER ON-SITE

By

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INTRODUCTION

The conventional method of treatment and disposal of on-site wastewater consists of the septic tank-soil absorption system (2). This is an adequate and economical method of wastewater disposal under proper soil conditions (5). Where poor soil conditions exist, alternative methods of treatment and disposal are relied upon (1,4). One such alternative involves the discharge of treated wastewater to surface waters. To prevent significant environmental impacts and public health problems, a highly treated and disinfected effluent will be required before surface discharge is a feasible alternative.

On-site wastewater treatment studies on sand filtration of septic tank and aerobic unit effluents have shown that a high quality effluent can be obtained (6). This paper concentrates on disinfection of on-site wastewater via dry fed chlorination of sand filter effluent. Evaluation of the chlorination unit was based upon the following criteria: 1. disinfection performance, 2. hypochlorite tablet uptake rate, and 3. maintenance requirements.

EXPERIMENTAL FIELD SET-UP

Intermittent sand filters and disinfection facilities were constructed and monitored at two home sites located on University experimental farms. The treatment system located at the Ashland Experimental Farm treated septic tank effluent while the treatment system at the Electric Research Farm treated aerobic unit effluent. The sand filters, utilizing commercially available sand, had an open sand surface with insulated wooden covers and were underdrained to collect the filter effluent. The effluent from the sand filter flowed by gravity through a commercially available dry-fed chlorinator and finally into a chlorine contact chamber. See Figure 1 and 2.

According to manufacturer claims, the chlorinator utilized was capable of treating flows up to 1500 GPD. It had a removable cover for maintenance purposes and contained an internal baffle for regulating and directing the flow. Calcium hypochlorite in the form of tablets that contain a minimum of 70% free chlorine were housed in 2-3" diameter plastic feed tubes with caps. The feed tubes were 24" in length and slipped through the removable cover. The chlorinator contained 4" diameter inlet and outlets and were installed in the level position to permit smooth flow.

Due to the low flow rates, 100 to 800 GPD, only one feed tube was charged with hypochlorite tablets. This tube was placed in the No. 1 position as shown in Figure 3. Each tube had a 29 tablet capacity; however, to prevent over chlorination only 5 to 10 tablets were kept in tube No. 1 during the experimental studies.

FIGURE 1. Dry Feed Chlorinator

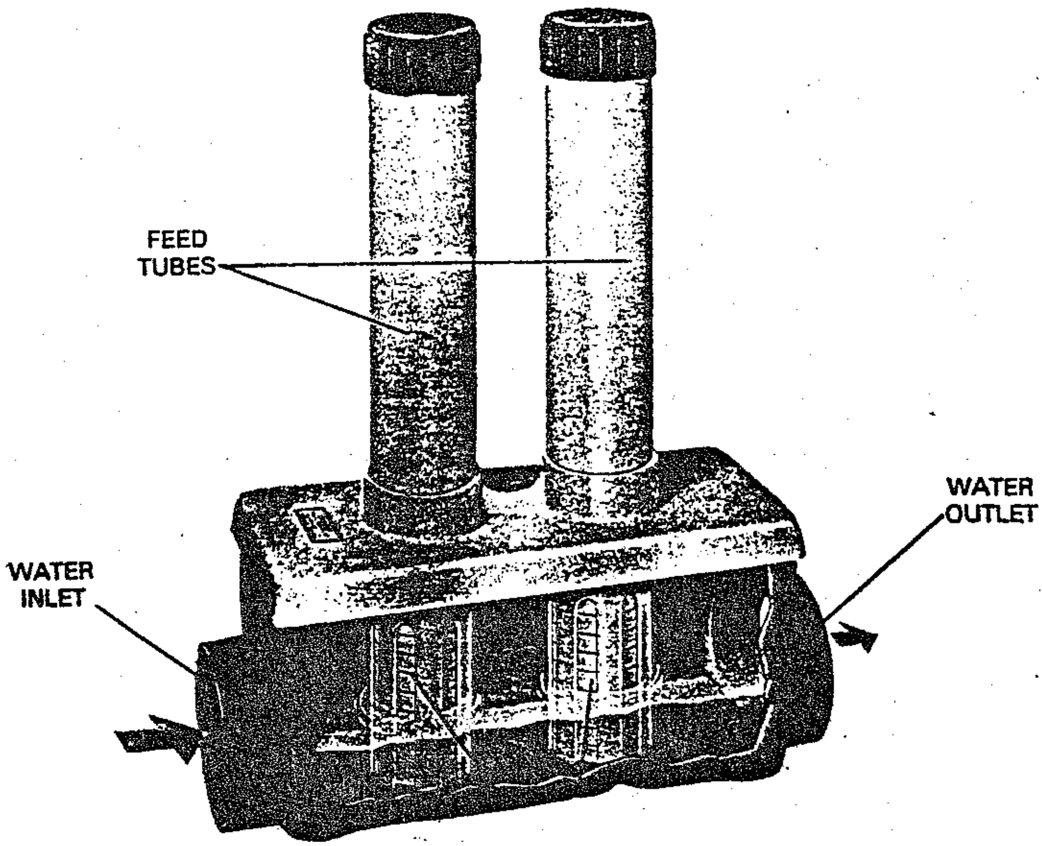
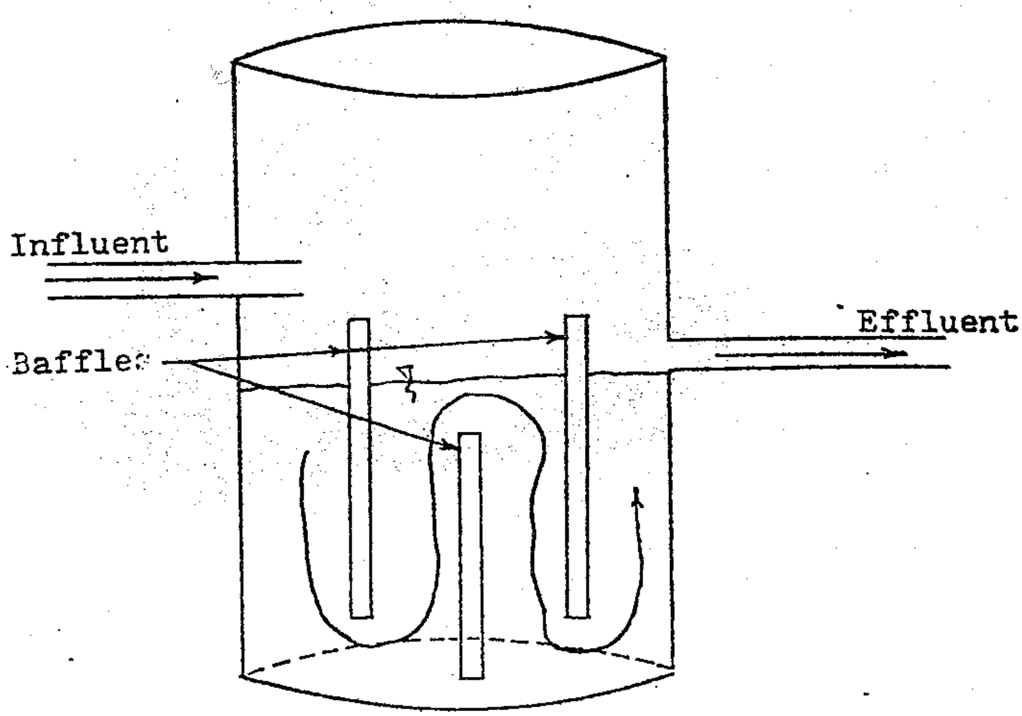


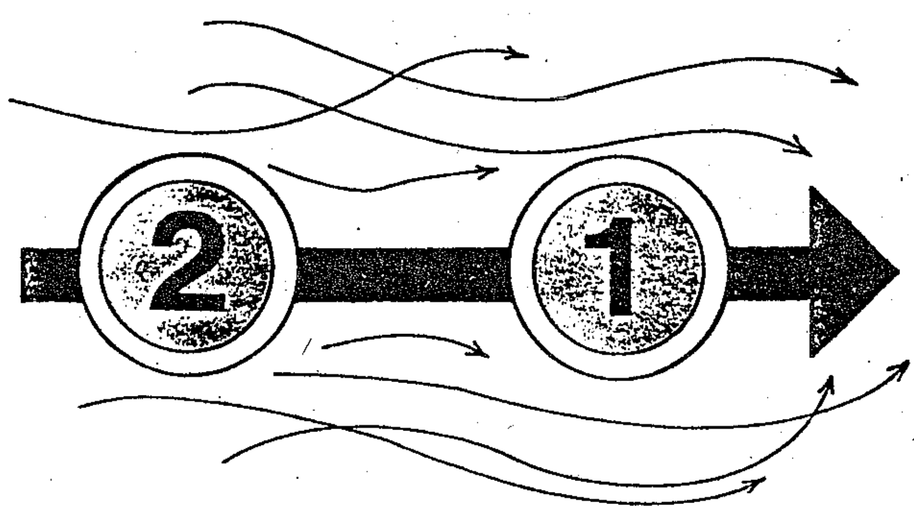
FIGURE 2. Chlorine Contact



As the effluent trickled through the chlorinator, the tablets slowly dissolved, thereby releasing chlorine. As the bottom tablets dissolved, the upper tablets dropped, coming into contact with wastewater and were also dissolved. Addition of replacement tablets and periodic cleaning were recommended as the only forms of maintenance to the unit.

The chlorine contact chamber allowed sufficient time for the chlorine to disinfect the wastewater. The contact chamber was 3' in diameter and was baffled as shown in Figure 2, to prevent short circuiting. The volume of the contact chamber at the Electric Research Farm was 114 gallons and, thus, provided an average detention time ranging from 14 to 17 hours. The volume of the contact chamber at the Ashland Experimental Farm was 150 gallons providing an average detention time from 3 to 21 hours.

FIGURE 3. Chlorinator Tube Arrangement



PRESENTATION AND DISCUSSION OF RESULTS

Disinfection Performance

To measure the effectiveness of the experimental disinfection unit, bacteriological analyses were performed on the disinfected effluent (6). Parameters monitored included fecal streptococci, pseudomona aeruginosa, fecal and total coliforms and total bacteria. Samples were taken weekly or bi-weekly from September, 1973 through March, 1975. Results of these tests are listed in Tables 1, 3 and 4.

Results from the disinfection of aerobic unit-sand filter effluent are shown in Table 1. Flow rates over the experimental period were approximately 150 GPD. Listed in Table 2 are surface discharge recommendations for primary contact recreational waters for fecal and total coliforms (8).

It is apparent that the chlorine contact chamber effluent met and exceeded by the 95% confidence interval, the requirements for surface discharge. Fecal strep. and Ps. aeruginosa were also significantly reduced.

Measurement of residual chlorine in the disinfected effluent is equally important when evaluating chlorinator performance.

TABLE 2. Recommendations for Surface Discharge for Primary Contact Recreational Waters

Fecal Coliforms	$\leq$ 200/100 ml
Total Coliforms	< 1000/100 ml

TABLE 1. Statistical Analysis of Bacterial Concentrations Through Aerobic Unit-Sand Filter - Disinfection System - (Sept. 1973-Feb. 1975)

Flow Rate 100 to 150 GPD

	Aerobic Unit Effluent	Sand Filter Effluent	Chlorine Contact Effluent
	D_T = 5 - 7 Days	L.R. = 3.8 GPD/ft^2	D_T = 14 - 17 Hrs.
Fecal Streptococci (#/100 ml)			
Mean	2.7×10^3	$(2.8-8.4) \times 10^2$	8
95% Conf. Int.	$(1.6-4.3) \times 10^3$	$(1.6-13.4) \times 10^2$	3-18
Range	$(0.02-120) \times 10^3$	$(0.03-220) \times 10^2$	0.2-7100
# of Observ.	52	50	52
Fecal Coliform (#/100 ml)			
Mean	1.9×10^4	$(1.3-2.8) \times 10^3$	8
95% Conf. Int.	$(1.4-2.7) \times 10^4$	$(0.9-4.4) \times 10^3$	3-20
Range	$(0.2-25) \times 10^4$	$(0.1-41) \times 10^3$	0.2-1300
# of Observ.	51	49	51
Total Coliform (#/100 ml)			
Mean	1.5×10^5	$(1.3-1.8) \times 10^4$	35
95% Conf. Int.	$(0.9-2.6) \times 10^5$	$(0.8-2.2) \times 10^4$	10-117
Range	$(0.06-8.0) \times 10^5$	$(0.06-120) \times 10^4$	0.2-55,000
# of Observ.	50	44	51
Total Bacteria (#/100 ml)			
Mean	3.2×10^7	$(4.8-10) \times 10^6$	3.7×10^5
95% Conf. Int.	$(2.3-4.5) \times 10^7$	$(3.4-14) \times 10^6$	$(1.2-11) \times 10^5$
Range	$(0.3-13.7) \times 10^7$	$(0.3-172) \times 10^6$	$(0.04-1450) \times 10^5$
# of Observ.	45	40	42
Pseudomonas aeruginosa (#/100 ml)			
Mean	2.2×10^3	$(0.2-0.3) \times 10^3$	5
95% Conf. Int.	$(0.8-5.6) \times 10^3$	$(0.1-1.0) \times 10^3$	2-13
Range	$(0.1-92) \times 10^3$	$(.004-24) \times 10^3$	2-240
# of Observ.	17	18	16

*Statistics based on log-normal distribution

High chlorine residuals have toxic affects on aquatic plant and animal life. Zillich (8) reported that chlorine residuals $\geq$ 0.04-0.05 mg/l caused lethal affects on fresh water fish. Of the 37 values of residual chlorine recorded over the experimental period, only 13 were $\leq$ 0.1 mg/l. This indicates that although good disinfection of the sand filter effluent was attained by the chlorinator, lack of sufficient control of the rate of application of hypochlorite caused toxic levels of residual chlorine to be present in the chlorine contact chamber effluent.

Acceptable discharge of this effluent to receiving waters is dependent upon the daily dilution effect. For example, assuming a 300 GPD household flow rate and a chlorine residual of 0.1 mg/l, a receiving water flow rate of $\geq$ 300 GPD would be necessary to prevent toxic effects on aquatic plant and animal life. However, for each additional 0.1 mg/l of chlorine residual, an increase in receiving water flow rate of 600 GPD would be necessary to dilute the chlorine concentrations to acceptable levels. The point should be made that acceptable concentrations of chlorine residual is determined entirely by a case by case basis dependent upon existing dilution effects.

Results from the disinfection of septic tank-sand filter effluent are shown in Tables 3 and 4. Table 3 contains data covering the period of October, 1973 - May, 1974 when flow rates through the systems were 400 to 800 GPD. Table 4 contains data covering the period of August, 1974 - March, 1975 when flow rates through the system were 200 to 400 GPD.

Under both flow rate conditions, bacteriological analysis show that the number of fecal and total coliform were below the surface discharge requirements for municipal wastewater, although slightly higher numbers were observed at the high flow rate.

Measurement of chlorine residual levels at both flow rates were quite high (0.1-1.0 mg/l). One chlorine residual was as high as 160 mg/l. As reported earlier, chlorine residuals $\geq$ 0.05 mg/l are toxic to aquatic plant and animal life (8). Again, acceptable discharge of this effluent to receiving waters is dependent upon existing dilution effects.

Hypochlorite Tablet Uptake Rate

During the operation of the disinfection unit, a record was kept of the amount of hypochlorite tablets utilized. Figure 4 is a graph of the hypochlorite uptake (tablet/1000 gal.) vs. flow rate (GPD). From the graph, disinfection of aerobic unit-sand filter effluent resulted in an uptake rate of 0.6 to 0.9 tablets/1000 gal. at the flow rate of 100-150 GPD. A distinct relation between uptake rate and flow rate cannot be established due to small range of operating flow rates. Disinfection of septic tank-sand filter effluent had an uptake rate inversely dependent upon the flow rate. At a flow rate of 200 GPD, the uptake rate was 1.5 tablets/1000 gal. while at a flow rate of 800 GPD the uptake rate was only 0.3 tablets/1000 gal. Apparently, at high flow rates the wastewater flows rapidly through the chlorinator, thus, limiting the contact time with the hypochlorite tablets. Since the uptake rate is expressed as tablets per 1000 gallon, the rate of

TABLE 3. Statistical Analysis of Bacterial Concentrations Through Septic Tank-Sand Filter - Disinfection System (Oct. 1973-May 1974)

Flow Rate 400 to 800 GPD

	Septic Tank Effluent D_T = 1.9 - 3.8 Day	Sand Filter Effluent L.R. 14 - 42 GPD/FT^2	Chlorine Contact Effluent D.T. = 4.5 - 9 Hrs.
Fecal Streptococci (#/100 ml)			
Mean	3.3×10^3	$(0.6-6.2) \times 10^2$	12
95% Conf. Int.	$(1.6-7.1) \times 10^3$	$(0.2-9.6) \times 10^2$	2-94
Range	$(0.2-21) \times 10^3$	$(0.02-15) \times 10^2$	0.2-3500
# of Observ.	15	11	14
Fecal Coliform (#/100 ml)			
Mean	5.4×10^5	$(2.7-9.8) \times 10^3$	61
95% Conf. Int.	$(2.7-10.7) \times 10^5$	$(0.5-52) \times 10^3$	5-794
Range	$(0.1-27) \times 10^5$	$(0.1-370) \times 10^3$	0.2-26,000
# of Observ.	14	11	15
Total Coliforms (#/100 ml)			
Mean	2.0×10^6	$(1.0-2.3) \times 10^4$	203
95% Conf. Int.	$(1.3-3.2) \times 10^6$	$(0.2-13) \times 10^4$	10-4260
Range	$(0.4-8.2) \times 10^6$	$(0.02-60) \times 10^4$	0.5-75,000
# of Observ.	15	11	13
Total Bacteria (#/100 ml)			
Mean	6.3×10^8	$(4.8-5.0) \times 10^7$	3.4×10^7
95% Conf. Int.	$(4.2-8.4) \times 10^8$	$(1.7-14) \times 10^7$	$(1.1-5.7) \times 10^7$
Range	$(0.005-11.9) \times 10^8$	$(0.7-29) \times 10^7$	$(0.01-9.1) \times 10^7$
# of Observ.	14	10	12

* Statistics based on log-normal distribution

TABLE 4. Statistical Analysis of Bacterial Concentrations Through Septic Tank-Sand Filter - Disinfection System (Aug. 1974-March 1975)

Flow Rate 200 to 400 GPD

	Septic Tank Effluent D_T = 3.8 - 7.5 Day	Sand Filter Effluent L.R. = 5 GPD/FT^2	Chlorine Contact Effluent D_T = 9 - 18 Hrs.
Fecal Streptococci (#/100 ml)			
Mean	3×10^3	$(0.4-0.9) \times 10^2$	2
95% Conf. Int.	$(1.4-6.5) \times 10^3$	$(0.1-1.6) \times 10^2$	0.6-7
Range	$(0.1-22) \times 10^3$	$(0.02 \times 473) \times 10^2$	0.2-160
# of Observ.	14	14	12
Fecal Coliform (#/100 ml)			
Mean	5.9×10^5	$(5.3-8.4) \times 10^2$	2
95% Conf. Int.	$(3.7-9.5) \times 10^5$	$(1.1-49) \times 10^2$	0.5-12
Range	$(1.4-19) \times 10^5$	$(0.01-420) \times 10^2$	0.5-14
# of Observ.	14	13	11
Total Coliforms (#/100 ml)			
Mean	9.0×10^5	1.3×10^3	3
95% Conf. Int.	$(5.5-15) \times 10^5$	$(0.2-9.5) \times 10^3$	0.5-16
Range	$(1.9-28) \times 10^5$	$(0.1-825) \times 10^3$	0.3-490
# of Observ.	12	12	11
Total Bacteria (#/100 ml			
Mean	2.0×10^8	$(4.6-7.8) \times 10^6$	1.0×10^5
95% Conf. Int.	$(0.8-3.1) \times 10^8$	$(0.8-58) \times 10^6$	$(0.1-7.9) \times 10^5$
Range	$(0.3-4.1) \times 10^8$	$(0.05-330) \times 10^6$	$(.001-72) \times 10^5$
# of Observ.	9	9	11
Pseudomonas aeruginosa (#/100 ml)			
Mean	3.0×10^3	17-41	< 2
95% Conf. Int.	$(1.2-7.0) \times 10^3$	5-140	< 2
Range	$(0.3-35) \times 10^3$	2-1300	< 2
# of Observ.	13	12	9

* Statistics based on log-normal distribution

erosion on a volume basis decreases at the higher flow rates. This relationship is exactly opposite of manufacturers claims. According to the manufacturers of the chlorination equipment, the rate of erosion of hypochlorite tablets should increase in proportion to an increase in flow rate.

Knowing the hypochlorite tablet uptake rate, an approximate cost of chemical for chlorination may be determined. Present cost of hypochlorite tablets ≈ $.53/tablet (3). From Figure 4, at a flow rate (septic tank-sand filter effluent) of 280 GPD, an uptake rate of 1 tablet/1000 gal. was found. Using these figures, the cost of chlorinating the 280 GPD flow for 1 year would be approximately $54. At a flow rate (aerobic unit-sand filter effluent) of 100 GPD, an uptake rate of 0.75 tablet/1000 gal. was found. Cost of chlorination of this flow for 1 year would be approximately $15.

Maintenance Requirements

Another important aspect in the evaluation of the chlorination unit was the amount and type of maintenance required for proper operation. With no mechanically moving parts in the chlorinator, the major maintenance was the addition of hypochlorite tablets to the unit. The frequency of this addition has been discussed above.

Another maintenance problem experienced during the study was the periodic failure of the hypochlorite tablets to move vertically downward as the bottom tablets dissolved. Apparently the tablets within the tube became somewhat moist and partially dissolved.

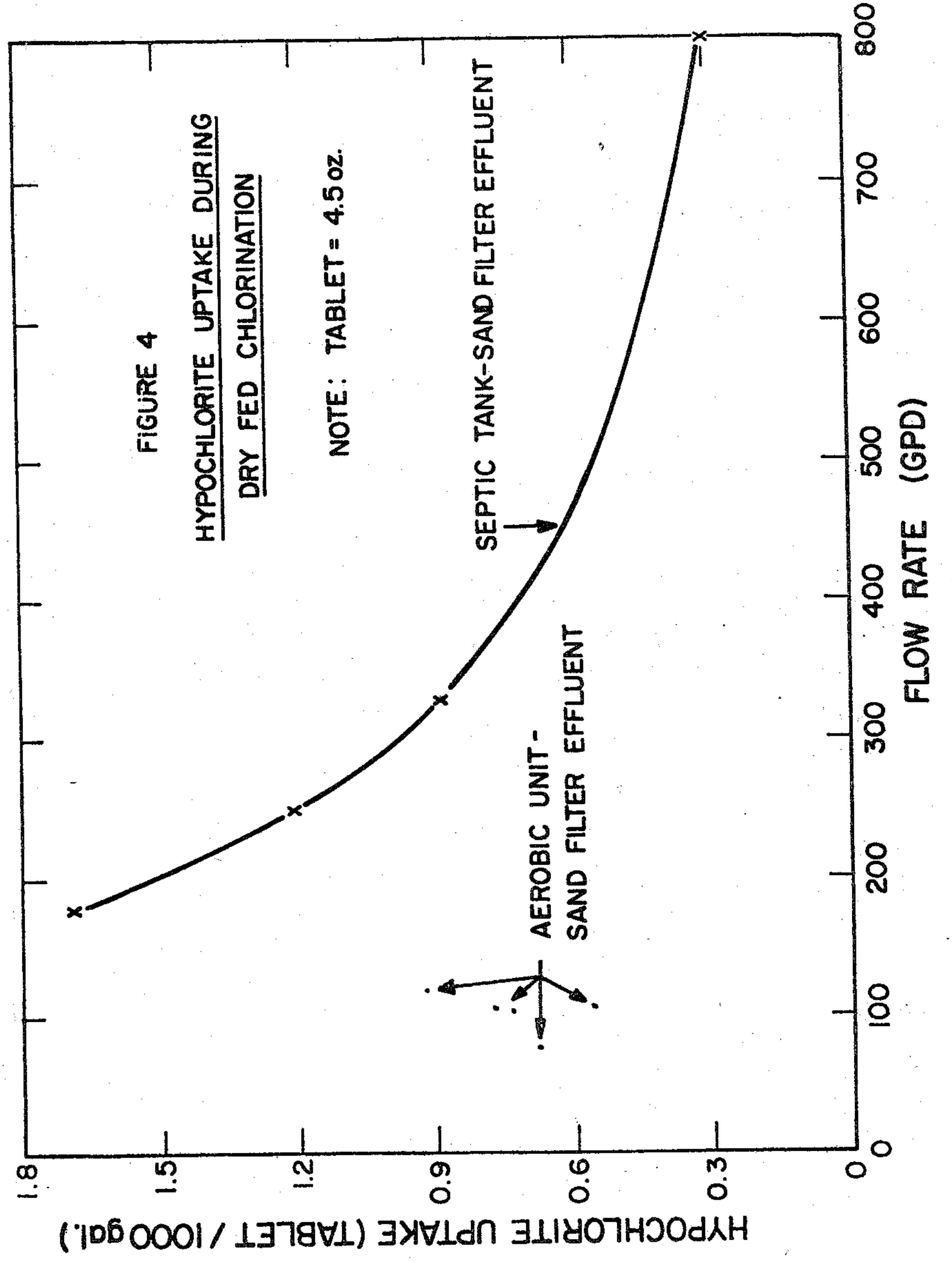


FIGURE 4
HYPOCHLORITE UPTAKE DURING
DRY FED CHLORINATION
NOTE: TABLET = 4.5 oz.
SEPTIC TANK-SAND FILTER EFFLUENT
AEROBIC UNIT-
SAND FILTER EFFLUENT
HYPOCHLORITE UPTAKE (TABLET / 1000 gal.)
FLOW RATE (GPD)
1.8
1.5
1.2
0.9
0.6
0.3
0
100
200
300
400
500
600
700
800

In the dissolved state the tablets adherred to the sides of the tubes, preventing downward movement as the lower tablets dissolved. It is speculated that part of the problem may be poor air ventilation. In northern climates where temperatures are below freezing, insulated covers must be used for the disinfection chamber. When this occurs, poor air ventilation results in a high moisture condition in the chlorinator causing the tablets to partially dissolve. Another possible reason for the problem could be due to the fact that only 5 to 10 tablets were kept in the chlorinator tube. Maintaining a higher number of tablets in the chlorinator tube could help force the tablets downward.

Another minor problem that reoccurred periodically was the breaking off of small pieces of hypochlorite within the chlorinator tube. These small pieces were carried by the wastewater flow from the chlorinator and into the contact chamber causing excessive amounts of chlorine in the treated wastewater as previously shown. The age of the hypochlorite tablets may have an affect on this; however, the manufacturer believes it to be due to poor tablet quality (3). Although control over tablet quality has increased over the past few years, it should be remembered that the problem does exist and probably will exist to some degree in the future.

To help control chlorine residuals, there are also a number of maintenance techniques utilized. One of these includes the placement of the chlorine feed tube slightly above the bottom of the chlorinator. This would prevent continuous contact of the hypochlorite tablets with the wastewater. Another adjustment would involve blocking some of the openings in the bottom of the chlorine tube. Again this would limit hypochlorite tablet contact with the wastewater. Finally, the chlorine tube could be placed in the number 2 position, Figure 3, where hypochlorite tablet uptake is less than in position number 1.

Another possible means of residual chlorine control could involve thiosulfate addition after chlorine contact. However, it is felt that this would not be too practical for individual systems. Finally, a by-pass system could be installed such that only a desired percentage of wastewater is directed through the chlorinator. The remaining flow would by-pass the chlorinator entirely.

CONCLUSIONS AND RECOMMENDATIONS

Experiments were conducted over an 18 month period to evaluate the use of dry feed chlorination equipment as a disinfection method for on-site wastewater. Two units installed and operated under field conditions were closely maintained and monitored. Significant conclusions and recommendations from the study follow:

1. Adequate disinfection of the sand filtered effluent was attained by chlorination. Concentration of fecal and total coliforms were below recommended surface discharge requirements for primary contact recreational waters.

2. Residual chlorine concentrations after 4.5 to 18 hours of contact time ranged from 0.1 to 1.0 mg/l. Since residual chlorine concentrations >0.05 mg/l can be toxic to aquatic plant and animal life, acceptable discharge of this effluent is dependent upon the dilution effects of the receiving water.

3. The chlorine uptake rate for the aerobic unit-sand filter effluent at a flow rate of 100-150 GPD was 0.6 to 0.9 tablets/1000 gal. The chlorine uptake rate for the septic tank-sand filter effluent was inversely proportional to the flow rate as shown in Figure 4. At 280 GPD, an uptake rate of 1.0 tablet/ 1000 gal. was found.

4. Using hypochlorite tablet uptake rates obtained from this study, approximate costs of chemicals for chlorination was determined. For flow rates of 100 to 280 GPD, the cost of chlorination ranged from $15 to $54 per year.

5. Although the chlorination does not have mechanical moving parts, periodic maintenance was required to insure proper operation. This maintenance included providing ample supply of hypochlorite tablets in contact with the wastewater.

6. One of the major problems associated with this dry feed chlorinator is the lack of control of the hypochlorite dose to the wastewater. Various maintenance techniques are described. These techniques require evaluation through field testing if such chlorinators are to be used as a final treatment before surface discharge of effluents.

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