

NUTRIENT REMOVAL AND SLUDGE DISPOSAL  
WITHIN SEPTIC SYSTEMS - PHASE III

By

Nicholas L. Clesceri

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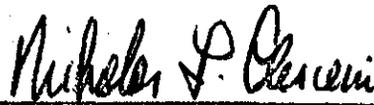
Rensselaer Polytechnic Institute

Dr. Nicholas L. Clesceri, Director  
Rensselaer Fresh Water Institute at Lake George  
Troy, New York 12181

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Nicholas L. Clesceri, Ph.D.  
Project Supervisor

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In 1972, it was reported that approximately 50 million people in the United States treated their wastewater with some 13 million septic tank systems (Ballentine, et al., 1972). This heavy reliance upon private rather than community waste treatment has resulted in a substantial dispersed flow of wastewater effluent into the environment. Moreover, these private systems cannot be monitored, in their operating efficiency, to the degree that community wide systems can be supervised. In many cases, inefficient operation of a septic tank system is remedied only after it has become an annoyance to its owner and his neighbors.

Septic tank systems function well in waste treatment only if they have been appropriately designed and maintained, and placed in an area where soil character and depth allow for sufficient aeration, filtration, microbial stabilization and ion exchange of the materials contained in the effluents. However, demand in the United States for private home ownership, and increasingly, second-home ownership, clearly over-ride the necessity for proper placement of septic tank systems. Within the drainage basin of Lake George, NY, for instance, bedrock lies very near to the ground surface and outcroppings are common. Soil cover is thin in many areas, particularly those immediately adjacent to the lake shore. The construction of private dwellings requiring septic tank systems has not been deterred, however.

The Rensselaer Fresh Water Institute (FWI) has underway a study which has, and is, investigating various aspects of this problem especially as it may concern the Lake George drainage basin. In one aspect of this study, chemical coagulation is to be evaluated as a method of enhancing the efficiency of waste removal within the septic tank itself, thereby reducing the material burden upon the receiving soil. Coagulation with alum is of special interest since the process is capable of removing soluble constituents from the waste effluent. Of particular concern is the removal of phosphates, a critical plant nutrient, whose presence in waste effluents has often been linked to nuisance growths of algae in receiving waters.

Where the soil character and depth are suitable, phosphates can be removed from the percolating septic tank effluent by various sorption phenomena. A second aspect of this study has been concerned with the capacity for phosphate removal by typical soils of the Lake George drainage basin. Evaluation of this nature can be of great value in the proper design of a septic tank system, particularly where low soil capacity may dictate more stringent requirements than those set by regulating agencies, e.g., the distance of the system from the lake shore.

#### A. CHEMICAL CHARACTERISTICS OF WASTEWATER IN A TEST SEPTIC TANK SYSTEM PRIOR TO IN-TANK TREATMENT WITH ALUM

The septic tank system under study is located in the Bolton Landing, NY area and has been serving a single household since the summer of 1974. A 1,000 gallon tank receives a daily flow of approximately 300 gallons of domestic waste year-round. Effluent is discharged to a 2,600 square feet leach field capable of sustaining an application rate of 1.0 gal/sq ft/day. Details of the system and site have been previously reported to the New York State Science and Technology Foundation (Clesceri, 1974). Sampling of the system began in February, 1975 and continued into July, 1975. The sole aim of this portion of the study was to characterize the constituent levels of the wastewater in its flow through the system, to provide the necessary baseline data once treatment with alum is initiated.

##### 1. Materials and Methods

Sample sets were collected from the system on a periodic basis. A set of samples consisted of five: viz. (1) a tap water sample collected in the basement of the house, (2) a septic tank sample taken approximately 2" to 3" below the surface of the liquid, (3) a septic tank sample taken approximately three feet below the liquid surface (at mid-depth), (4) a sample of the tank sludge taken approximately 1" off the bottom of the tank, and (5) a sample taken from the pump well, again,

approximately 1" from the bottom of the well. Samples 2, 3, and 4 were taken through the same tank port, and sample 5 was taken through the well port, using a hand type bilge pump, to which was connected a six foot length of CPVC pipe, 3/4" I.D. An eight inch length of rubber hose joined the pipe to the pump. The unit was primed and the first half-liter of sample was discarded before collection began.

Samples were pumped into one quart polyethylene containers, pH measurements were made with a Chemtrix Model 40E meter, following which mercuric chloride was added to the samples at a level of 40 mg/l for preservation.

Nonfiltrable solids were collected on Whatman GF/C glass fiber filters. The filters were pre-weighed and following filtration of 50 ml of sample, dried at 105 C for one hour. After reweighing, fixed nonfiltrable solids were determined by ashing the filters at 525 C for one hour.

Alkalinity of the samples was determined by potentiometric titration with 0.02  $N$   $H_2SO_4$ . A Beckman Century SS pH meter was employed.

Dissolved organic carbon was measured by combustion of a filtered sample (0.5 micron filter) by direct injection into a tube-furnace. 5.0 ml of each filtered sample was first acidified with 0.2 ml of 0.5  $N$   $H_2SO_4$ , and stripped with nitrogen gas for three minutes prior to injection. The  $CO_2$  resulting from combustion was measured with non-dispersive infrared instrumentation (Mine Safety Appliance LIRA Model 200 Analyzer).

Nitrogen and phosphorus components were determined with a Technicon AutoAnalyzer II system. Ammonia was measured by the phenoxide/hypochlorite procedure (Technicon Method No. 154-71W); nitrate by Technicon Method No. 158-71W; and filtrable reactive phosphorus by an automated molybdate/ascorbic acid method.

Total Kjeldahl nitrogen and total phosphorus were measured by the same procedures, following manual acid digestion. Kjeldahl nitrogen was obtained with sufluric acid digestion, using selenium as a

catalyst (Technicon Method No. 146-71A). Total phosphorus was obtained with potassium persulfate digestion (Standard Methods Procedure 223 C. III, 13th Ed., 1971).

## 2. Results and Discussion

Results of the chemical analyses are presented in Tables 1 through 5. Tap water (Table 1) for the household is pumped from groundwater and shows the influence of the late winter-early spring snow-melt period. The lower alkalinity values during this period result in part from the dilution by snowmelt, and in part from neutralization by acid components of precipitation, which are substantial for this region. Concurrent higher values for both ammonia- and nitrate-nitrogen are anticipated since precipitation is also the major source of nitrogen to the Lake George drainage basin.

In the septic tank, the sludge layer (Table 4) consists of 3.2% total solids on the average, of which 22.1% are fixed solids, 4.0% are Kjeldahl nitrogen and 1.0% is total phosphorus. If the volatile solids are assumed to be organic matter only, an approximate carbon content of 41% (of total solids) may also be assumed. A C:N:P of 38.5:4.0:1.0 can then be calculated. Bernhart (1973) reports a representative C:N:P value of 41:7:1, which is of the same order as that in the test system. The test system values are biased since no correction has been made for phosphorus associated with the inorganic fraction of the sludge.

The chemical composition of the liquid in the tank (Tables 2 and 3) shows a high buffering capacity, capable of maintaining a suitable pH environment for the necessary microbial stabilization processes. In the course of stabilization, ammonia-nitrogen and phosphate-phosphorus are released from the waste material in amounts which generally exceed the requirements of the microbial population. Phosphorus concentrations are high; the filtrable reactive phosphorus (FRP) is nearly double the representative figure (i. e.,  $2 \times 10^{-4}$  M) presented in Part B of this report. The ammonia-nitrogen is also predictively high, but nitrate-nitrogen reflects denitrification activity which is expected in an anaerobic environment.

Septic Tank Study: Analysis Key for Sample Results

1. pH      pH as units
2. ALK     Alkalinity as mg CaCO<sub>3</sub> per liter
3. DWT     Total nonfiltrable solids as mg per liter; Sludge layer: total solids as mg per liter
4. ASH     Total nonfiltrable fixed solids as mg per liter; Sludge layer: total fixed solids as mg per liter
5. DOC     Filtrable organic carbon as mg C per liter
6. AMM     Ammonia as mg N per liter
7. TKN     Total Kjeldahl nitrogen as mg N per liter
8. NIT     Nitrate as mg N per liter
9. TP       Total phosphorus as mg P per liter
10. TSP     Total filtrable phosphorus as mg P per liter
11. FRP     Filtrable reactive phosphorus as mg P per liter

TKN and TP results are reported for the sludge layer  
(Table 4) as milligrams per gram of dry sludge.

Results prefixed with a " - " should be read as "less than."

TABLE 1  
Chemical Analysis of Tap Water

DATE	pH	ALK	AMM	TKN	NIT	TP	TSP	FRP
02/28/75		25.7	0.034	0.11	0.79			
03/07/75		31.7	0.039	0.12	0.40			
03/14/75	7.32	32.1	0.044	0.16	0.48	0.005	0.004	-0.002
03/21/75	6.19	27.6	0.034	0.14	1.52	0.013	0.006	-0.002
03/28/75	5.93	30.5	0.092	-0.10	0.79	0.016		
04/18/75	6.06	35.1	0.066	0.10	0.59	0.005		
04/25/75	6.78	37.9	0.104	0.25	0.41	0.002		
05/01/75	6.48	37.0	0.043	-0.10	0.32	0.003		
05/08/75	6.44	47.8				-0.002	-0.002	
05/16/75	6.21	46.5	0.020	-0.10	0.15	-0.002	-0.002	-0.002
05/22/75	6.42	46.5				-0.002	-0.002	
05/30/75	6.58	52.7	0.044	0.16	0.063	0.006	0.004	
06/13/75	5.98	44.3				-0.002	-0.002	
06/20/75	6.54	51.8	-0.010	0.20	0.34	-0.002	-0.002	-0.002
06/27/75	6.21	45.5				-0.002	-0.002	
07/03/75	6.64	53.0	-0.010	0.14	0.12	-0.002	-0.002	-0.002
07/10/75			0.013	-0.10	0.27	0.004	0.003	-0.002

TABLE 2

## Chemical Analysis of Top Layer of Septic Tank

DATE	pH	ALK	DWT	ASH	DOC	AMM	TKN	NIT	TP	TSP	FRP
02/28/75		300	167	0	20	51	75	0.007	15.4	12.6	12.0
03/07/75		329	170	0	30	70	93	0.006	14.4	11.4	11.0
03/14/75	7.71	428	186	32	30	88	105	0.004	22.0	19.6	19.0
03/21/75	7.17	323	187	29	16	65	97	0.006	17.4	14.8	14.0
03/28/75	7.55	373	116	0	22	76	100	0.016	22.8	20.2	20.0
04/18/75	7.05	305	143	0	17	50	60	0.012	11.8	9.2	9.0
04/25/75	7.78	328	173	0	17	58	92	0.005	15.0	11.0	10.0
05/01/75	7.09	330	171	0	26	63	84	0.002	14.2	11.6	11.0
05/08/75	7.46	317	177	0	14						
05/16/75	7.61	260	254	99	14	52	66	0.004	8.1	6.4	2.8
05/22/75	7.04	243	158	0	17						
05/30/75	7.39	260	220	2	29	44	76	0.002	8.5	6.4	5.2
06/13/75	7.26	293	118	0	21						
06/20/75	7.40	319	124	17	22	55	80	0.011	11.0	9.5	8.8
06/27/75	7.52	383	311	61	29						
07/03/75	7.55	421	247	36	33	77	92	0.005	14.0	12.0	11.0
07/10/75			193	18	31	55	87	0.029	15.0	11.0	10.0

TABLE 3

## Chemical Analysis of Middle Layer of Septic Tank

DATE	pH	ALK	DWT	ASH	DOC	AMM	TKN	NIT	TP	TSP	FRP
02/28/75		320	131	0	29	60	72	0.006	15.2	13.4	13.0
03/07/75		332	135	0	24	72	90	0.003	13.4	11.8	11.0
03/14/75	7.80	420	91	0	22	84	105	0.003	21.0	19.0	19.0
03/21/75	7.23	320	111	10	20	80	93	0.012	21.0	16.8	16.0
03/28/75	7.22	398	169	4	14	65	100	0.006	24.2	15.4	15.0
04/18/75	7.21	316	179	0	18	58	86	0.002	12.6	10.0	10.0
04/25/75	7.26	315	204	0	18	61	97	0.003	15.6	11.4	11.0
05/01/75	7.28	336	136	0	19	64	87	-0.002	14.6	12.0	12.0
05/08/75	7.42	312	169	0	12						
05/16/75	8.16	264	177	59	10	51	62	-0.002	7.6	6.8	4.2
05/22/75	7.31	268	78	0	18						
05/30/75	6.86	265	144	11	14	43	46	0.005	7.6	5.5	4.8
06/13/75	7.00	298	118	0	20						
06/20/75	7.45	348	101	1	23	64	73	0.003	12.0	11.0	9.8
06/27/75	7.56	401	145	29	35						
07/03/75	7.11	417	126	0	28	73	80	0.012	14.0	12.0	11.0
07/10/75			110	0	28	68	89	0.008	14.0	12.0	10.0

TABLE 4  
Chemical Analysis of the Sludge Layer

DATE	DWT	ASH	TKN	TP
02/28/75	27360	6390	26.7	9.9
03/07/75	43580	14460	30.1	10.3
03/14/75	32450	7240	26.5	6.5
03/21/75	29660	6200	29.0	10.1
03/28/75	37880	9980	32.2	5.8
04/18/75	30010	4780	47.3	12.0
04/25/75	24720	4040	42.1	8.5
05/01/75	22980	4040	38.7	7.0
05/08/75	36010	9490		
05/16/75	36970	8170	49.8	11.9
05/22/75	29950	6100		
05/30/75	32300	6960	50.2	11.1
06/13/75	33510	6790		
06/20/75	28689	6378	55.1	15.0
06/27/75	43645	8422		
07/03/75	28578	5623	60.5	16.8
07/10/75	28000	5878	57.1	12.1

TABLE 5

## Chemical Analysis of Pump Well Liquid

DATE	pH	ALK	DWT	ASH	DOC	AMM	TKN	NIT	TP	TSP	FRP
02/28/75		325	668	435	26.0	64.0	83	0.017	22.2	8.2	8.0
03/07/75											
03/14/75	7.66	442	412	200	91.0	84.0	121	0.004	21.4	18.2	18.0
03/21/75	7.19	96	935	684	7.1	6.0	11	1.000	2.1	0.6	0.6
03/28/75	7.34	355	232	92	17.0	67.0	80	0.017	21.2	19.0	18.0
04/18/75	7.14	326									
04/25/75	7.34	283	231	12	20.0	50.0	66	-0.002	12.4	8.8	8.5
05/01/75	7.40	345	226	35	34.0	67.0	84	-0.002	14.4	11.8	11.5
05/08/75	8.01	280	404	209	31.0						
05/16/75	7.64	268	1769	1558	22.0	49.0	72	0.007	8.1	6.4	5.0
05/22/75	7.03	263	188	80	22.0						
05/30/75	7.02	229	103	11	22.0	34.0	45	0.019	6.0	5.1	4.2
06/13/75	7.15	274	295	148	41.0						
06/20/75	7.47	315	742	596	17.0	54.0	63	0.006	9.4	7.2	6.0
06/27/75	7.62	324	100	25	23.0						
07/03/75	7.01	325	376	231	23.0	71.0	97	0.030	13.0	12.0	11.0
07/10/75			1039	863	21.0	20.0	42	0.035	3.8	1.4	1.3

Nonfiltrable solids, i. e., particulate matter, appears to be primarily organic, although fixed solids may be present at any time in substantial quantity. The surface layer (Table 2) appears to contain higher amounts of fixed solids, and probably reflects the presence of the scum layer which receives solids directly from the raw waste as well as from the sludge layer as a consequence of methane, and other gas, production.

Within the distribution system, the pump well samples (Table 5) indicate that leakage of surface water is occurring. This factor is evidenced by the sharply decreased concentrations of phosphorus and ammonia-nitrogen that are found, together with increased concentrations of nitrate-nitrogen. The latter are considerably higher in precipitation (as compared to septic tank levels). Additionally, fixed and total nonfiltrable solids are also found to be significantly higher in the pump well. These solids are likely soil particles entering with the infiltration. The degree of interference in the pump well sample, would have varied with the amount of infiltration occurring prior to activation of the pump, and the time of sampling in relation to pumping. Given this variability, a better indicator of nutrient loading to the leach field would be the mid-layer of the septic tank from which the pump well draws.

#### B. PHOSPHORUS SORPTION CHARACTERISTICS OF SIX SOILS IN THE LAKE GEORGE, NY DRAINAGE BASIN

Differences in soil types in the Lake George drainage basin, especially with regard to clay content, pH, and depth to bedrock, suggest considerable variation in phosphorus (P) sorbing capacities among the soils. These differences, in turn, should influence the design of septic systems including the need, in some cases, for chemical treatment of septic effluent to reduce its P concentration.

The parameter most frequently used as an index of different soils' P sorption capacities has been the P adsorption maximum. This is obtained by shaking small quantities of soil for lengthy periods of

time with solutions of different concentrations of inorganic P. Plots of the amount of P sorbed at constant temperature by the soil,  $X/M$ , versus the concentration of P remaining in the solution after the shaking period,  $C$ , are called adsorption isotherms. These are used to estimate the P adsorption maximum, the sorption of P at various initial concentrations of inorganic P, and sorption of P at different equilibrium P concentrations.

In 1971, Bache and Williams (1) proposed a phosphate sorption reference index for soils based on the slope of a plot of the sorption of P,  $X/M$ , against the logarithm of the equilibrium solution P concentration,  $\log C$ , at  $C = 10^{-4} \underline{M} P$ . The authors obtained good correlation between this index and the sorption,  $X/M$ , at an equilibrium concentration,  $C$ , of  $10^{-4} \underline{M} P$ . More recently, Sawhney and Hill (7) used the sorption at an equilibrium concentration of  $2 \times 10^{-4} \underline{M} P$  to determine the phosphate sorption characteristics of several Connecticut soils treated with domestic wastewater. The equilibrium concentration of  $2 \times 10^{-4} \underline{M} P$  corresponds to approximately the concentration of P in wastewater (6.2 ppm P), and the amount of P sorbed by the soil at this equilibrium concentration can be obtained readily from a plot of  $X/M$  vs  $C$ .

The objectives of this study were: 1) to examine differences in P sorption among soils representative of those found in the Lake George drainage basin, and 2) to develop a rapid soil test to estimate the P sorption capacities of the soils.

### 1. Materials and Methods

Soil samples representing the A, B and C horizons of six soil series in the Lake George drainage basin were collected during July and August, 1974. All samples were obtained from the Town of Queensbury in Warren County.

The samples were air-dried and passed through a 2 mm sieve. To determine P sorption capacities, duplicate 2.5 g samples of soil were shaken with 25 ml of 0.01 N NaCl containing varying amounts of inorganic P as  $KH_2PO_4$  for 72 hours at  $20 \pm 1^\circ C$ . Each sample was

treated with at least ten different equilibrating solutions which ranged from 2 to 80 or from 2 to 120 ug P/ml, depending on the soil.

Samples of the Charlton and Madalin B horizons received in addition a 200 ug P/ml solution, while the Deerfield A and B horizons were also equilibrated with 200 and 300 ug P/ml solutions.

The soil-solution suspensions were filtered, after shaking, through a glass fiber filter and an underlying millipore (.45 u) filter. An automated procedure using the method of Murphy and Riley (6) was employed to measure the orthophosphate content of the filtrates. Phosphorus sorbed by the soil was calculated on the basis of the difference between the P concentration of the equilibrating solution and that found in the filtrate.

In a rapid soil test procedure designed to measure P sorbed during a very short contact time with an equilibrating solution, duplicate 2.5 g samples were shaken with 25 ml of 0.01 N NaCl containing 20 ug P/ml for 15 minutes at  $20 \pm 1^\circ$  C. Filtrates were obtained and analyzed for P as described above.

Soil pH was determined on a 1:1 soil:water suspension using a pH meter. The hydrometer method was used to determine soil texture (particle size analysis).

## 2. Results and Discussion

The pH, textural class, and clay content of samples of the A, B and C horizons of each soil series used in the study are shown in Table 6.

### P Sorption Capacities of Soils

Sorption of P by the samples varied considerably with both soil type and with soil horizons. The isotherms shown in Figure 1 illustrate the marked differences in sorption by the Deerfield A horizon and the Oakville A, B and C horizons. The values of C identified on each of the isotherms are the equilibrium P concentrations resulting from contact between the soil and a solution initially containing 20 ug P/ml. For example, when a 20 ug P/ml solution was shaken with the Deerfield A samples, the P concentration of the solution was reduced to

TABLE 6  
 pH, Textural Class, and Percentage Clay  
 of Soil Samples Used in P Sorption Study

Soil Series	Horizon	pH	Textural Class	% Clay
Madalin	A	7.2	sandy clay loam	33
	B	7.8	clay loam	36
	C	7.6	silty clay loam	24
Oakville	A	5.1	sandy loam	5
	B	5.6	loamy sand	4
	C	6.0	sand	2
Deerfield	A	6.2	sandy loam	8
	B	6.6	sandy loam	10
	C	6.4	loamy sand	5
Charlton	A	5.2	sandy loam	13
	B	6.0	sandy loam	18
	C	5.9	sandy loam	8
Ridgebury	A	5.7	sandy loam	13
	B	6.1	sandy loam	8
	C	6.5	sandy loam	9
Windsor	A	5.4	loamy sand	5
	B	5.4	loamy sand	8
	C	5.7	loamy sand	1

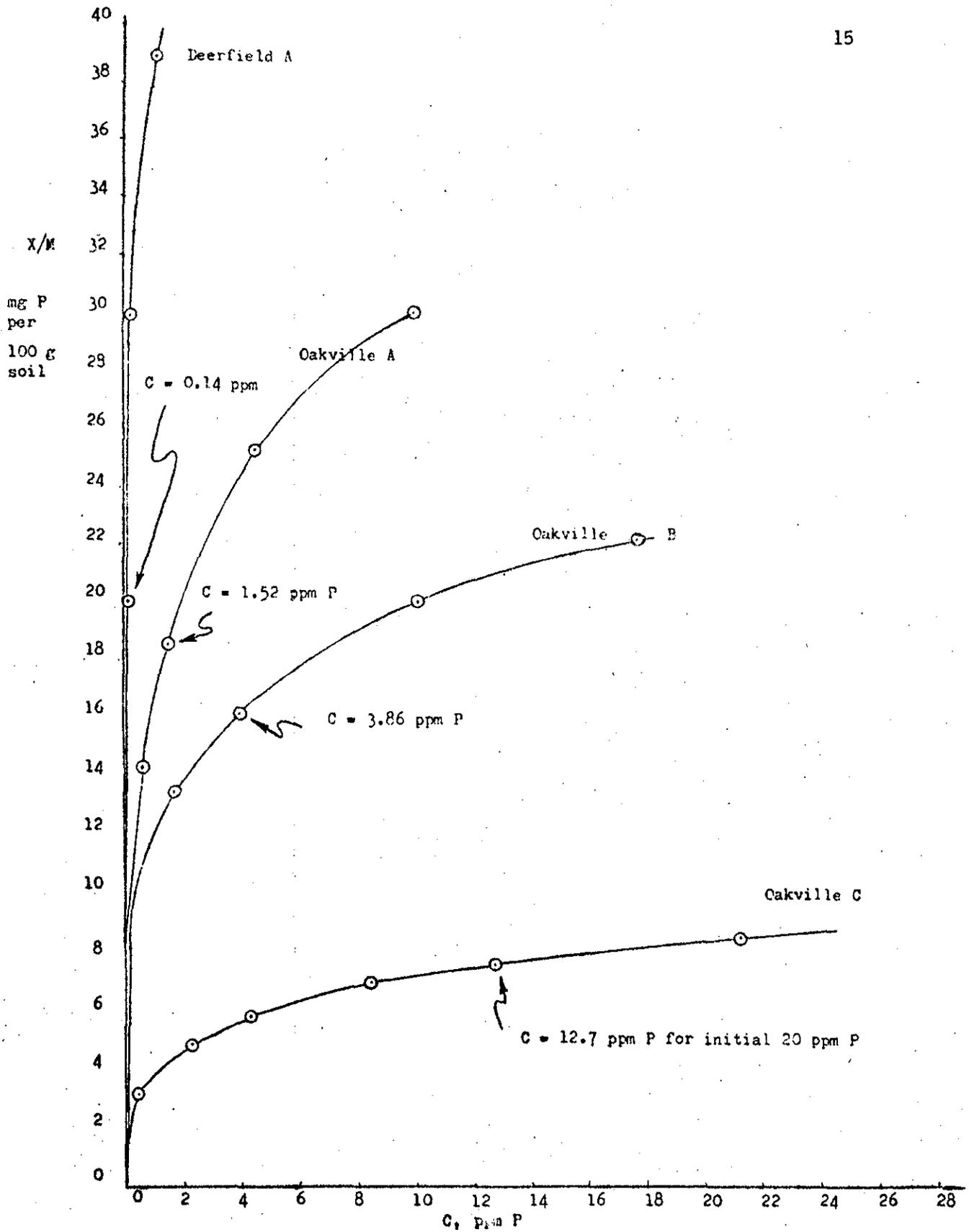


FIGURE 1. P Sorption Isotherms for Soil Samples of Oakville A, B and C Horizons and Deerfield A Horizon Showing Equilibrium P Concentrations Resulting From Contact With Solutions Initially Containing 20  $\mu$ g P/ml.

0.14 ppm P after 72 hours of shaking, compared to 12.7 ppm P for the Oakville C samples. Thus, the Deerfield A samples removed much more P from solution than did any of the Oakville samples.

An appropriate reference index for P sorption by the soils used in this study is the sorption at an equilibrium concentration of  $2 \times 10^{-4}$  M P (6.2 ppm P), the approximate concentration of soluble orthophosphate in wastewaters. The values in Table 7 show the amounts of P sorbed by the soils when the equilibrium P concentrations were  $2 \times 10^{-4}$  M. These values were obtained from adsorption isotherms constructed for each soil.

The Table 7 figures further illustrate the differences among soils and soil horizons in their ability to remove P from solution. For example, samples of Deerfield B horizon sorbed over 10 times as much P as Oakville C samples at an equilibrium P concentration of  $2 \times 10^{-4}$  M. The B horizon of the Charlton fine sandy loam, probably the most commonly occurring of the six soils in the Lake George drainage basin, had a sorption capacity nearly twice that of the C horizon. It should be noted that the B horizon of each soil had a higher sorbing capacity than the C horizon. Similar results were reported for Michigan soils by Ellis and Erickson (5), who pointed out that many tile drain fields are likely to be laid below the B horizon, thereby minimizing or eliminating sorption of P by this horizon.

The sorption data can also be examined in terms of the length of time required to saturate a soil with P. Assuming a loading rate of 1.8 kg P/yr (3.96 lbs P/yr) of soluble inorganic P from a household of four and a soil volume of 1200 cubic feet surrounding the tile drain field (5), the times needed for saturation of the soil with P (i. e., times required for soil to sorb the amount of P at equilibrium with  $2 \times 10^{-4}$  M P) can be calculated. Thus, saturation would occur in 1.7 years for the Oakville C horizon, in 4.4 years for Charlton C, in 7.7 years for Charlton B, and in 18.3 years for Deerfield B. Bulk density values of 1.40 g/cc are assumed for each soil.

It should be emphasized that these times are relative. Actual

TABLE 7

P Sorption by Soils as Measured by Amounts of P Sorbed at Equilibrium Concentrations of  $2 \times 10^{-4}$  M P (6.2 ppm P) and Amounts of P Sorbed by Soils During 15-minute Shaking Period with One Solution Containing 20 ug P/ml

Soil Series	Horizon	Sorption at	Sorption in 15 min.
		C = $2 \times 10^{-4}$ M P	from 20 ug P/ml solution
		mg P/100 g soil	
Madalin	A	22.3	10.5
	B	38.4	15.8
	C	23.8	12.0
Oakville	A	26.9	11.2
	B	17.7	9.9
	C	6.3	2.7
Deerfield	A	61.0	15.0
	B	69.0	15.1
	C	11.8	6.3
Charlton	A	15.6	8.7
	B	29.1	11.2
	C	15.9	8.6
Ridgebury	A	28.1	11.3
	B	11.8	6.3
	C	9.9	5.3
Windsor	A	23.6	9.4
	B	25.2	10.4
	C	12.2	7.5

times will change with the P concentration of the septic effluent, the volume of soil in the drain field, the soil's bulk density, the period of time the household is occupied each year, and most importantly, the regeneration of P sorption sites with time. Both Sawhney and Hill (7) and Ellis and Erickson (5) observed considerable regeneration with time and concluded that effective P sorption capacities of soils are much greater than values obtained from laboratory sorption studies. Regeneration would undoubtedly be of particular importance when residences are occupied for only two or three months out of the year. This is the case with many summer residences near Lake George.

#### Rapid Test to Estimate P Sorption Capacities

Obtaining accurate P sorption isotherms for soils is time-consuming and tedious. Therefore, a procedure to estimate the soils' P sorption capacities using only one solution (20 ppm P) and a 15 minute shaking period was used. Amounts of P sorbed by the soils under these conditions are shown in Table 7.

It was found that a plot of the natural logarithm of the amount of P sorbed at equilibrium with  $2 \times 10^{-4} \text{ M P}$  (72-hour shaking period) versus P sorbed in the rapid test (Figure 2) resulted in a straight line with the following equation:

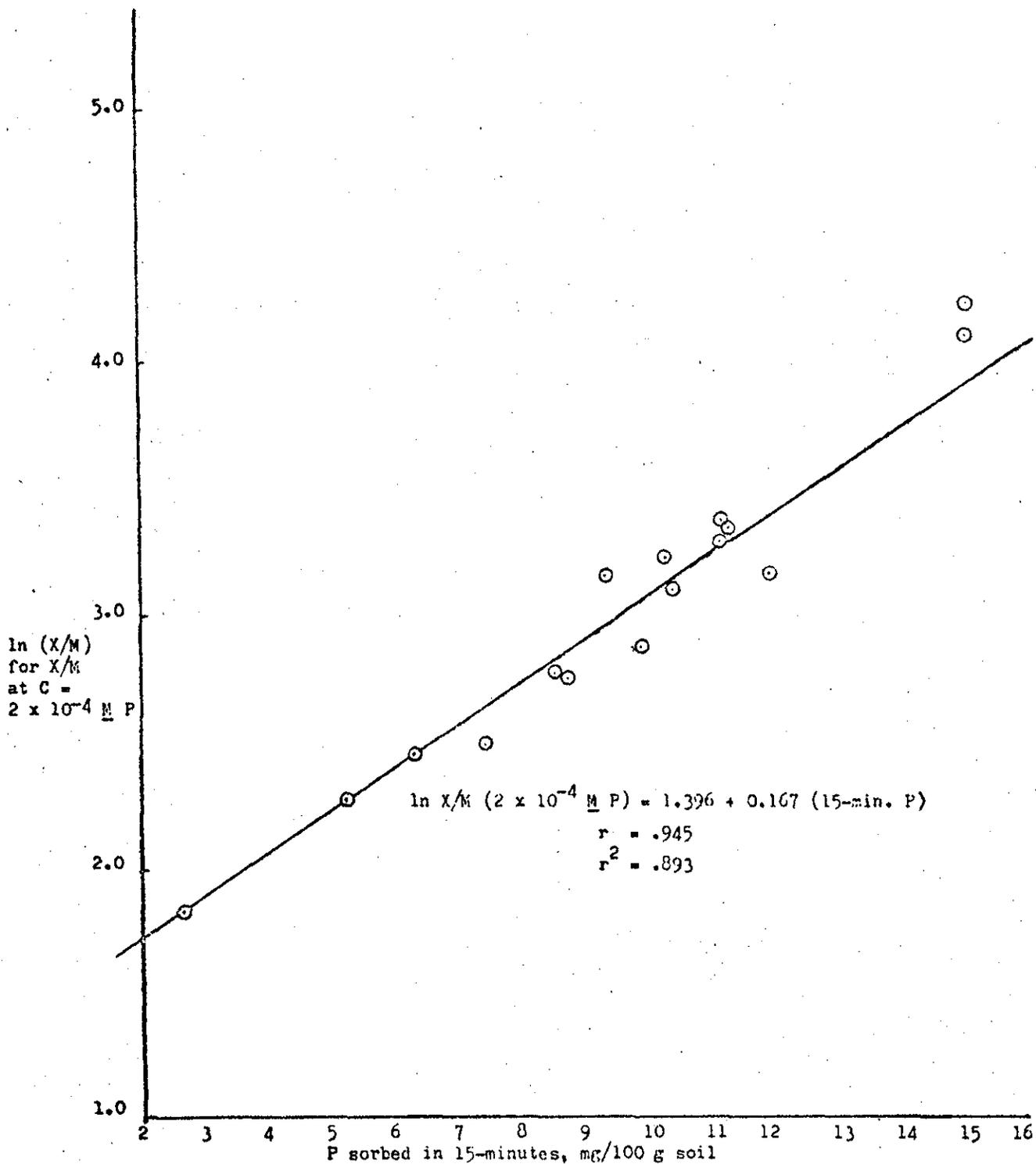
$$\ln X/M (2 \times 10^{-4} \text{ M P}) = 1.396 + 0.167 ("15\text{-min P}"); \quad r = .945 \\ r^2 = .893$$

The equation can be rearranged as follows:

$$X - M (2 \times 10^{-4} \text{ M P}) = e^{1.396 + 0.167 ("15\text{-min P} ")}$$

Excluding the results for the Madalin soil, which is much higher in clay than any of the other soils, increases the correlation coefficient to 0.966 and  $r^2$  to .932.

Thus, by measuring P sorption from one solution for a short period of time, a reasonable estimate of a soil's P sorption capacity can be obtained. This value, in turn, can be used in conjunction with data on the design and use of a domestic septic system to obtain relative estimates of the time required for saturation of the drain field with P (or the volume of soil needed in the drain field to allow operation of the



**FIGURE 2.** Plot of the Natural Logarithm of P Sorbed at Equilibrium Concentration of  $2 \times 10^{-4}$  M P vs P Sorbed in 15-Minutes from Solution Containing 20  $\mu$ g P/ml.

septic system for a given number of years). These estimates will be conservative because of regeneration of P sorption sites in the soil, a process which requires further study and quantification.

### C. ESTIMATED LOADINGS OF PHOSPHORUS FROM THE TEST SYSTEM

From the physical characteristics given for the test system, i. e., 300 gallons of wastewater flow per day to a leach field with a total area of 2600 square feet and a depth four feet below the leach trenches (Clesceri, 1974), and the phosphorus data presented in Table 3, phosphorus loadings and saturation times can be estimated. Average phosphorus concentrations are: for FRP, 11.3; for TSP, 12.1; and for TP, 14.8 mg P/l, respectively. With the given wastewater flow, the phosphorus loadings are then: 4.68 kg FRP per year, 5.02 kg TSP per year, and 6.13 kg TP per year.

Assuming that the total volume of the leach field is effective in sorption processes, then 294.5 square meters of fill is the quantity of soil with which the effluent will be in contact. Again, assuming a bulk density of 1.40 gm per cc for the soil (as in Part B), the soil has an  $M = 4.12 \times 10^5$  kg.

From Table 7, the typical soils for the Lake George basin vary considerably in their phosphorus sorption capacity, both with character and horizon. The average X/M value is 22.1 mg P per 100 gms. Saturation times for the different soils are presented in Table 8.

What must be kept in mind in considering an estimate of 19 years for saturation, is that the test leach field is over-sized, being designed to receive the effluents from two septic tanks. In fact, saturation times are undoubtedly closer to the estimates presented in Part B, for the usual leach field. These figures emphasize the applicability for in-tank removal of phosphorus, in extending the useful life of a septic tank system.

TABLE 8  
Estimated Saturation Times for the Test Septic Tank System

Capacity	Bed Capacity (kg P)	Estimated Saturation Time in Years		
		FRP	TSP	TP
Low	26.0	5.5	5.2	4.2
Average	91.3	19.5	18.2	18.2
High	284.5	60.8	56.7	46.4

## REFERENCES

1. Bache, B. W., and E. G. Williams. 1971. A Phosphate Sorption Index for Soils. *J. Soil Sci.* 22:289-301.
2. Ballentine, R. K., S. R. Reznick, and C. W. Hall. 1972. Sub-surface Pollution Problems in the United States. U.S. Environmental Protection Agency Technical Studies Report TS-00-72-02.
3. Bernhart, A. P. 1973. Treatment and Disposal of Waste Water from Homes by Soil Infiltration and Evapotranspiration. Univ. of Toronto Press, Second Ed., Vol. 1.
4. Clesceri, N. L. 1974. Phase II Interim Progress Report on: "Phosphorus Removal Within Individual Septic Tank Systems." Rensselaer Fresh Water Institute Report No. 74-11 (in compliance with NYSSTF Proposal Register No. SSF(73)-(11)).
5. Ellis, B. G., and A. E. Erickson. 1969. Movement and Transformation of Various Phosphorus Compounds in Soils. Mimeo Report, Michigan State University.
6. Murphy, J., and J. P. Riley. 1962. A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. *Anal. Chim. Acta.* 27:31-36.
7. Sawhney, B. L., and D. E. Hill. 1975. Phosphate Sorption Characteristics of Soils Treated with Domestic Wastewater. *J. Environ. Qual.* 4:342-346.