THE LAKE GEORGE VILLAGE (NY)
LAND APPLICATION SYSTEM

BY

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FWI Report #78-1

CASE STUDIES

THE LAKE GEORGE VILLAGE (NY) LAND APPLICATION SYSTEM

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The Lake George Village Sewage Treatment Plant has been applying unchlorinated secondary treated effluent onto natural delta sand beds by rapid infiltration since 1939. The sand system has been shown to remove nonconservative materials such as BOD, COD, alkybenzenesulfonates, coliforms and fecal coli and ammonia and organic nitrogen. Soluble inorganic materials such as sodium, chloride, potassium and nitrate generally pass through the sand system. Calcium and magenesium showed no significant changes. Alkalinity increased due to carbonate and bicarbonate reactions within the soil. Orthophosphates were completely removed in the top 3 m of the sand beds and nitrates were removed in beds which were 18 m in depth or more.

Sewage flows vary from approximately 1,900 m^3/day in winter to 4,700 m^3/day during the summer tourist season. Dosing of the sand beds is intermittent with average overall loading rates of 0.12 m/day and actual infiltration rates of 0.08 to 0.3 m/day depending on the depth of water on the bed and the time since the last cleaning. The operation has continued successfully throughout the cold winter months experienced in this area.

The greatest removal of constituents occurred in the top 10 m of the sand beds. Continued quality improvement was observed in the further vertical flow and the approximately 600 m of horizontal flow before the applied effluent reemerges as seepage along the south bank of West Brook, a tributary to Lake George. There were no indications that the soil's capacity to treat the applied sewage effluent was approaching exhaustion.

INTRODUCTION

In 1936 there was concern for the potential pollution of beautiful Lake George by the increase in population at the southern end of the lake around the Village of Lake George. In order to prevent any contamination of the lake, a sewage treatment plant was designed. The inclusion of a land application system in this design was to comply with the regulation that there shall be no discharge of sewage or sewage effluent into any waters of Lake George or into any streams flowing into the Lake (1).

DESCRIPTION OF THE TREATMENT SYSTEM

The treatment plant as it exists today, is shown in Figure 1. The original plant put into operation in 1939 was built in triplicate to accommodate the summer tourist flows which were approximately 3 times the winter permaent population flows. The sewage from the Village is collected in a central sump where it is pumped by force main a distance of approximately 1.6 km to the treatment plant. After metering, the sewage flows through one of the three two-stage settling tanks with separate sludge digestion compartments, through one of three dosing chambers serving the siphons which are used to provide sufficient head to spread the water onto one of three trickling filters. Two of the trickling filters are of the high-rate rotary distributor type and are used in the summer. The third is a low-rate fixed nozzle filter which is covered by boards on sawhorses and used exclusively in the winter. After secondary sedimentation the unchlorinated final effluent is applied to the rapid infiltration sand beds. The original fixed beds (north beds 1-6) are in continual use to this day. The sand is a naturally occurring delta sand deposit which was deposited by the melting glacier approximately 10,000 years ago.

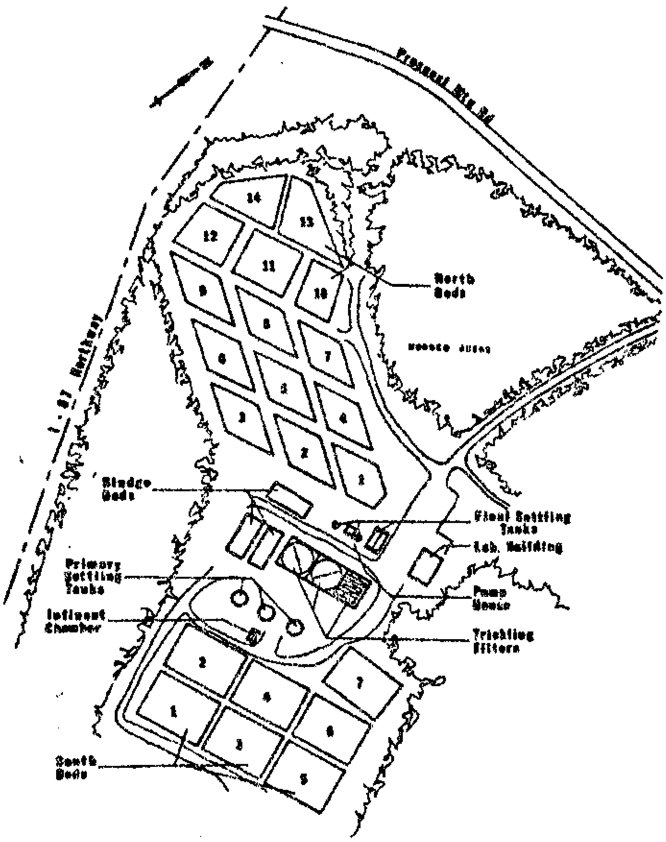

Figure 1. Plan of the Lake George Sewage Treatment Plant

The treatment plant has had 5 additions to the initial 6 sand beds since it was built. The major addition of south beds 1-6 and beds N-13 and -14 was made in 1965 when a new sewer system was built to serve the adjacent Town of Lake George. The present total infiltration area of the sand beds is 2.15 ha. The combined digested sludges are dried on adjacent sand beds and the dried sludge is removed to a landfill west of the treatment plant. The sand beds have operated satisfactorily through the rather severe winters of the area. Winter temperatures may reach as low as -35°C and periods of at least 33 days of continuous below freezing temperatures have been recorded. No chlorination is applied anywhere within the sewage treatment plant.

The lower (north) sand beds are all dosed by gravity, whereas the upper (south) beds are serviced by means of a pump. Normal operation of the infiltration beds is to dose one north and one south bed from 8 a.m. to 4 p.m. and another similar pair of beds from 4 p.m. to 8 a.m. On week-ends or holidays, two north and two south beds are dosed simultaneously for a 24-hour period. The beds normally drain in 1 to 3 days depending upon the amount of sewage applied and the time since the last cleaning. The design is to allow the beds to dry for at least one day between dosing. Occasionally, during extreme high summer flows, this rest period may become shortened or nonexistent. Periodically, at least twice a year, the beds are drained and any clogging material is removed along with the top few cm of sand which is disposed of in the areas adjacent to the sand beds. The bed is then plowed and releveled prior to being returned to service. Weed growths within the sand beds are considered undesirable and are normally removed as soon as possible.

BACKGROUND

In his original description of the treatment plant, Vrooman (2) stated that "the final effluent becomes ground water which in all probability seeps eventually, to some water course as a highly purified liquid which cannot be identified as a sewage effluent". However, this was purely speculation based on reasonably understood principles and it remained until the present authors made additional studies in the area to prove the validity of this statement. Studies made by Fink (3) measuring ground water resistivity indicated a band of low resistivity ground water following in a generally northerly direction along Gage Road toward West Brook (See Figure 2). With this information available, a survey was made of the south shore of West Brook in the vicinity of Gage Road. Considerable seepage was observed coming out of the ground along the south bank of West Brook at the edge of the flood plain. Conductivity measurements taken of this seepage showed the highest concentration of total dissolved solids to be in the closest proximity to Gage Road with the exception of some runoff which was later traced to an area where the highway department had stored highway de-icing salt uncovered on the surface of the ground for several years (4).

EXPERIMENTAL PROCEDURES

In order to study the quality of the ground water between the infiltration beds and the seepage along the south bank of West Brook, a series of observation wells was placed in this area as shown in Figure 2. The well points were located at different depths within the aquifer. In addition to the sampling wells, sampling stations were set up at the location of the two seepages prior to their flow into West Brook, and in West Brook upstream and downstream from the seepage areas. Seepage above (west of) Gage Road collects naturally in a small stream which discharges into West Brook immediately upstream from the culvert under Gage Road. The seepage in the area downstream (below Gage Road) was more diffuse, so a ditch was dug to consolidate these seepages into one stream. The seepages were monitored for flow and samples secured before discharge into West Brook.

Specific data for the depths of the individual wells, the approximate ground water levels within the wells and the bed rock or rejection point for the wells is shown in Table 1. In all cases, for each well site the depth of the points was lower with the notation proceeding through the alphabet from A (AA) to D. The steel wells consisting of a steel point and screen and iron pipe were manually driven. The wells marked P were augered with a 10 cm auger and then a plastic screen and pipe were placed in the hole. Use of the plastic pipe lessened contamination of the sample due to metals, primarily iron which may interfere with phosphorus measurements. As

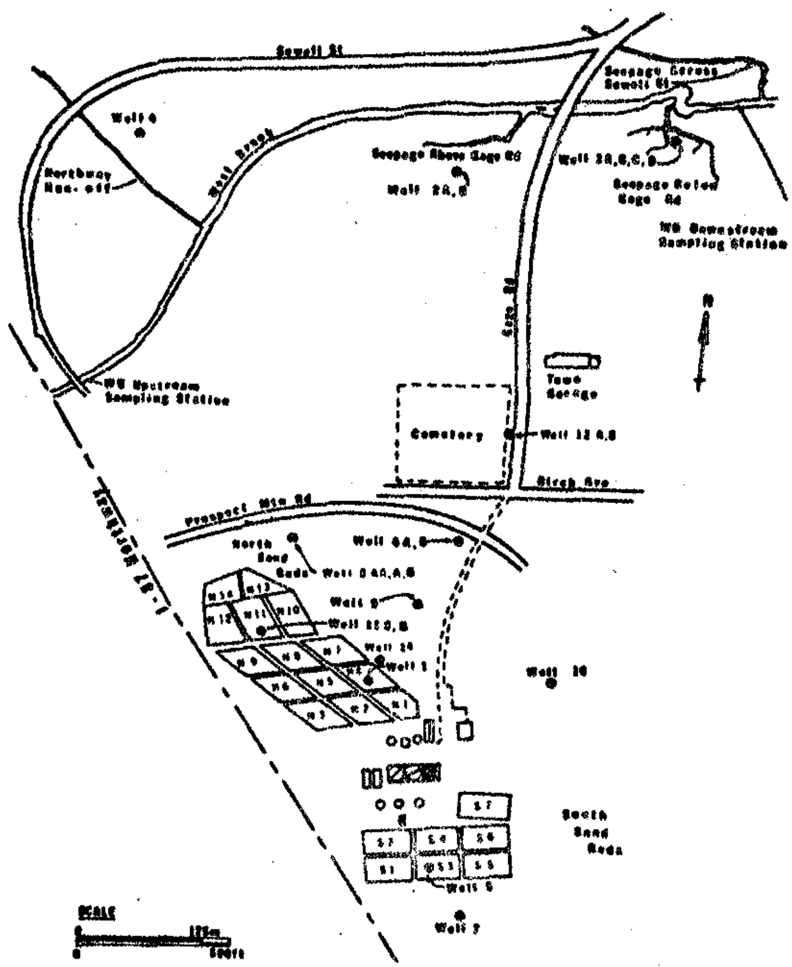

Figure 2. Map of the General Area of Study Showing the Observation Wells and Other Sampling Points.

TABLE I. WELL DATA
(Elevations in m. Above Mean Sea Level)

Location	Steel or Plastic	Top of Well	Ground Surface	Approx. Ground Water	Bottom of Point	Bedrock
1	P	145.57	144.77	126.47	124.44	123.48
2A	P	115.25	114.45	109.28	107.36	93.29
2B	S	115.44	114.45	109.31	100.72	93.73
3A	P	104.05	103.63	103.47	102.57	95.73
3B	P	104.19	103.63	103.52	100.32	95.73
3C	P	104.35	103.63	103.54	97.94	95.73
3D	S	103.73	103.63	103.44	96.23	95.73
4	S	115.68	114.52	114.50	112.65	112.65
5	P	152.50	151.03	147.22	146.16	145.55
6A	P	140.03	139.73	120.92	118.68	109.76
6B	S	140.25	139.85	120.59	109.76	109.76
7	S	153.85	152.53	151.55	150.47	150.47
8AA	P	143.37	143.30	123.48	121.96	118.38
8A	P	143.66	143.21	122.03	121.21	118.38
8B	P	143.68	143.29	122.02	118.38	118.38
9	S	143.11	142.28	123.10	120.58	120.58
10	S	141.80	141.08	134.66	133.81	133.81
11S	S	144.98	143.95	124.06	121.09	115.91
11D	S	145.17	143.95	123.81	117.40	115.91
12A	P	136.04	135.69	117.54	116.55	109.05
12B	P	136.06	135.71	117.04	109.07	109.07
14	S	144.27	143.80	125.81	124.61	124.00

the wells were put into service, samples were removed from them by pumping (in the shallower wells) or by means of a bailer. The first samples were secured in 1973; the major portion of the study was completed by the end of 1976. Some sampling and analysis are still being performed. In general, samples were secured on a bi-weekly basis.

In addition to the observation wells to determine changes in water quality with horizontal distance, studies were undertaken to determine the change in quality with depth in bed N-11. A series of driven well points, suction lysimeters, and pumping wells were installed in this sand bed as shown in Figure 3. Here again, the normal sampling procedure was bi-weekly, although during the flow tracer study to determine the velocity of flow through the sand bed, the pumped wells were monitored continuously.

In general samples were secured in rinsed plastic containers, returned to the laboratories, and analyzed as soon as possible. Preservation with mecuric chloride was performed in the field for all portions of the samples to be analyzed for nitrogen and phosphorus. All analyses were conducted according to Standard Methods (5).

INFILTRATION RATES

Infiltration rates were estimated based on the amount of sewage applied to each sand bed, the time it took for the sewage to drain through a bed, and the frequency of dosing. Since precise flow data to each sand bed are not available, it was assumed that half of the flow reaches the treatment plant from 8 a.m. to 4 p.m. and the other half of the daily flow occurs during the 16 hour night time period. Since two beds are dosed simultaneously during each period, it was assumed that each bed dosed received approximately one quarter of the daily flow. This value may not be entirely accurate since the lower north beds are dosed continuously by gravity and the upper south beds are dosed intermittently by means of a pump which is actuated by the depth of the water in a wet well filled by the flow over an adjustable weir in the pipe to the north beds. Time and facilities were not available for the actual measurements of the flow to the upper beds or the time of operation of the pump to the upper beds. It is felt that dividing the flow equally between the north and south beds provides a reasonable estimate for

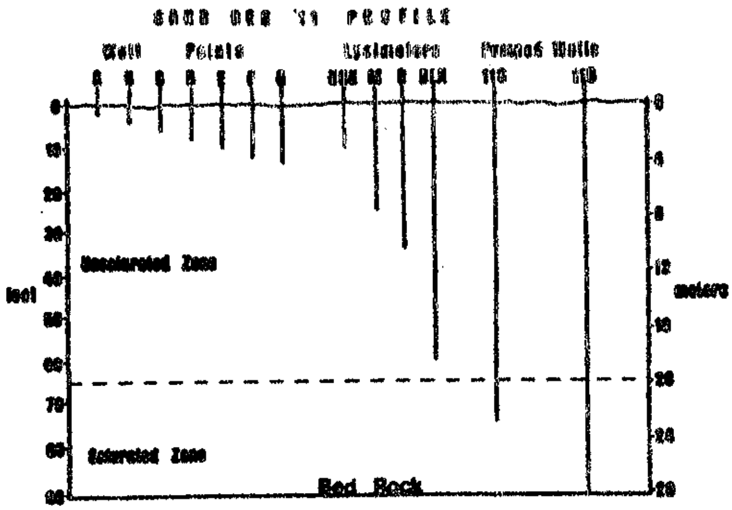

Figure 3. Profile of Bed N-11 Showing the Depths of Driven Well Points, The Operational Lysimeters and the Shallow and Deep Pumped Wells, The Latter Two of which Penetrate into the Saturated Aquifer.

calculation of the loading rates.

The estimated monthly loading rates for a 12 month period are shown in Table 2 (6). The maximum loading rate occurred during the month of August with a loading of 1.37 m^3/ha-min or 0.2 m/day. This represents the amount of liquid that can be safely applied to the sand beds without exceeding the total infiltration capacity. It must be mentioned, however, that during the latter part of August 1975 and 1976, the sand beds were all completely loaded and the normal drying time between dosing was either very short or non-existent. After the tourists departed after Labor Day, the flows diminished markedly and the sand beds were allowed to dry and were scraped, thereby increasing the infiltration capacity.

The actual infiltration rate was measured in several of the sand beds by installing a water level recorder in those beds. The rate of infiltration increased with the head of liquid on the sand beds as shown in Figure 4 (6). The lowest rates recorded with less than 0.3 m of liquid on the sand bed were in the range of 0.8-0.18 m/day under normal operating conditions. It may be seen that different beds have different infiltration rates, with bed S7 having a rate exceeding 0.3 m/day with a water depth on the bed of 0.6 m. An infiltration rate exceeding 0.6 m/day was measured on a freshly scraped bed with a depth of water of 0.3 m. With continued intermittent operation the flow rate decreased gradually to the values previously stated.

PURIFICATION WITH DEPTH IN THE UNSATURATED ZONE

All of the studies relating to the purification of the sewage effluent applied to the sand bed as a function of depth within the unsaturated zone in the sand bed were conducted in North Bed 11. The driven well points in this bed (Figure 3) were essentially ineffective from the standpoint of securing samples. The samples secured from the 4 operating lysimeters at depths of 3, 7, 11, and 18 m provided most of the information for the changes with depth in the unsaturated zone. Samples were also secured from the 2 pumped wells within the aquifer at 23 and 28 m depths, to evaluate the quality of the water in the saturated zone immediately beneath the sand beds.

Temperature measurements showed that the applied sewage effluent temperature varied with the ambient air temperature, whereas the temperature near the bottom of the unsaturated zone showed a lesser degree of fluctuation. Within the saturated zone the temperature range throughout the entire year was between 8 and 13^{o}C.

There was little significant difference in pH at various depths. The lowest value observed was 6.5 at the 11 m depth in fall and the highest was 7.4 in well 11S during the summer.

TABLE 2
WASTEWATER LOADING RATES, LAKE GEORGE, NY

Month	Flow	Loading Rate	
	10^6 l/d	l/m^2-d	m/d
1974			
Sep	2.80	1.11	0.13
Oct	2.23	0.89	0.10
Nov	1.57	0.62	0.07
Dec	1.86	0.74	0.08
1975			
Jan	1.89	0.75	0.09
Feb	1.94	0.77	0.09
Mar	2.15	0.85	0.10
Apr	2.66	1.05	0.12
May	2.50	1.00	0.12
Jun	2.95	1.17	0.14
Jul	3.67	1.46	0.17
Aug	4.24	1.70	0.20
Average	2.54	1.01	0.12

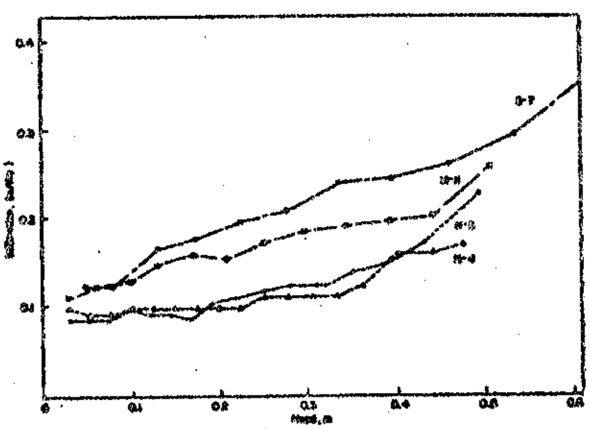

Figure 4. Comparison of the Infiltration Rates of Several Sand Beds in Normal Use

There was a consistent slight increase in dissolved solids concentration with depth during all seasons. The highest value of 300 mg/l occurred during the summer and the lowest (175 mg/l) during the winter. In the saturated zone immediately beneath the bed values never exceeded 125 mg/l, indicating the influence of the ground water in this area.

The principle of intermittent dosing of the sand beds is to allow the beds to become aerated between dosing, thus promoting aerobic treatment of the applied waste effluent. Measurements of the DO with depth showed the lowest values to be approximately 2.5 mg/l at the 18 m depth and in well 11S. These lowest values occurred during the fall and winter. The redox potential was determined only during the spring of 1976 and was positive at all times with the one exception being the 18 m depth at which point it was only slightly negative. The redox potential variation coincides fairly closely with the DO level variations measured in Bed N-11.

The highest chloride concentration of 100 mg/l occurred during the winter which is also the time of the greatest use of highway deicing salt. There was no significant change in the chloride content with depth in the sand beds.

The calcium content of the applied sewage effluent was approximately 20 mg/l with no significant changes in concentrations with depth within the unsaturated zone of Bed N-11. There was even less variation in magnesium content with depth, maintaining an average value of approximately 6 mg/l.

There was a consistent trend of an increase in alkalinity from about 100 mg/l in the applied sewage effluent to approximately 250 mg/l at the 18 m depth. There seems to be some relationship between alkalinity and pH and DO. As the alkalinity increased, the pH and DO decreased indicating the possible presence of microbial activity which utilizes oxygen, producing CO_2 which ultimately converts carbonates to bicarbonates which are measured as alkalinity.

There appears to be an inter-relationship between the organic, ammonia and nitrate nitrogen in the soil (8). During all seasons, there was a decrease in ammonia and organic nitrogen within the top 3 m of the sand bed with a consequent increase in the nitrate content at this depth. However, for summer and fall there appeared to be a subsequent decrease in nitrate with a significant increase in the organic and ammonia nitrogen at the 7 and 11 m depths. By the 18 m depth both the organic and ammonia nitrogen contents were less than 8 mg/l during the summer and fall compared to 16-18 mg/l of nitrogen applied to the sand bed. During spring there was no recurrence of the high ammonia and organic content at greater depths. Instead, values of organic, ammonia and nitrate nitrogen were all less than 0.5 mg/l. The changes in nitrogen compounds with depth during the spring in Bed N-11 are shown in Figure 5, with the depth of bed S-3 indicated on this figure for comparison. The upper dotted line

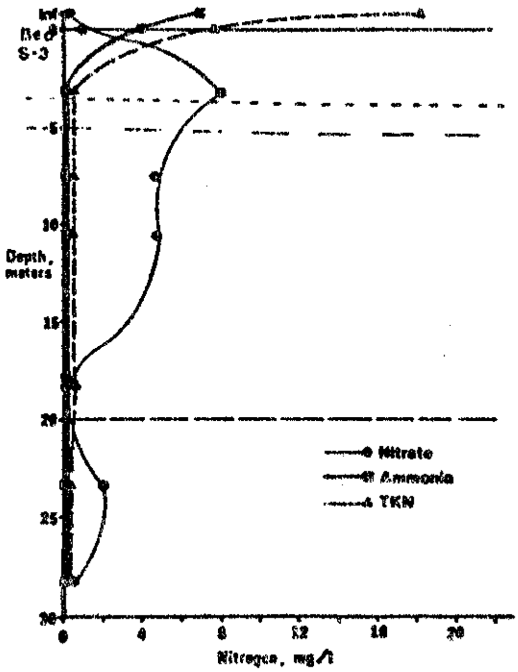

Figure 5. Variation of the Various Forms of Nitrogen Measured with Depth in Bed N-11 During Spring 1976. The Depth of Bed S-3 is Shown for Purposes of Comparison.

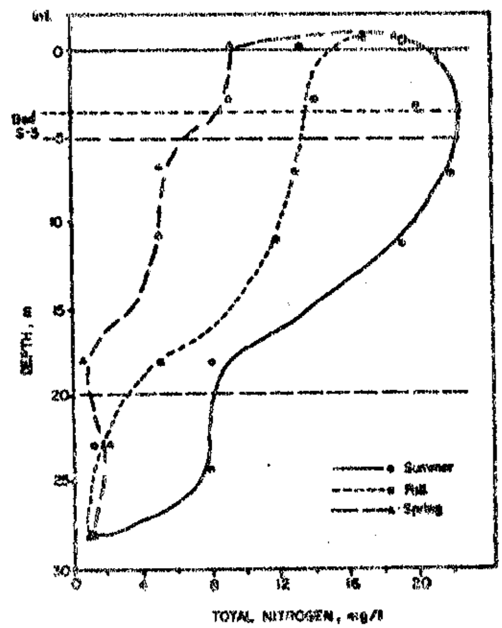

Figure 6. Variations in Total Nitrogen During Summer, Fall and Spring with Depth in Bed N-11, with the Depth of Bed S-3 Shown for Comparison.

indicates depth to water in bed S-3 and the upper dashed line the bedrock in bed S-3. The lower dashed line indicates the depth to water in Bed N-11; below this level of 20 to 22 m the sand is saturated with water. The high nitrate content at the 3 m depth also has significance in terms of other less deep infiltration beds. Some of the beds have only about 3 m of unsaturated zone followed by another 2 m of saturated zone above the bedrock. In these sand beds the oxidation of organic and ammonia nitrogen to the nitrate would result in nitrate entering the saturated zone and being carried through the soil. This could account for the elevated nitrate concentration measured in the ground water as described in the next section.

The loss of nitrogen from the aqueous system probably to elemental nitrogen is shown in Figure 6 in which the various forms of nitrogen are added for each season. The greatest loss of nitrogen occurred during spring. The loss of nitrogen corresponds with a low DO and a slightly negative redox potential at the 18 m depth in spring, and is assumed to represent reduction of nitrate.

In general the orthophosphate content was reduced from approximately 1.4 mg/l in the applied wastewater to 0.1 mg/l by the time the sewage effluent reached the 7 m depth. The total phosphorus indicated some initial reduction after 3 m vertical movement followed by higher values at greater depths. The highest values observed in the shallow pumping well were approximately 0.4 mgP/l of total phosphorus (8).

There were significant fluctuations during various seasons in the iron content at various depths. In general there was an increase in iron content with depth, with values varying between 0.5 and 8 mg/l. No direct relationship could be made between the iron content, pH, DO, redox potential or phosphorus content.

There were no significant changes in the sodium or potassium content of the applied sewage effluent as related to depth. The average sodium content was approximately 14 mg/l and the average potassium content was approximately 6 mg/l.

Other parameters measured included BOD, COD, alkylbenzenesulfonates, coliform and fecal coli all of which were essentially removed in the top 3 m of the unsaturated zone of the sand bed. Preliminary measurements were made for copper; however, all of the concentrations were less than 0.5 mg/l which is the lowest detectable limit using the atomic absorption spectrometer system used. Aluminum was not found within the detectable limit of about 1 mg/l.

PURIFICATION WITH DISTANCE IN THE SATURATED ZONE

After the applied sewage effluent flows vertically through the unsaturated zone of the sand beds it flows approximately another 600 m northward through the saturated zone before it emerges as seepage along the south banks of West Brook. This distance provides some additional purification of the liquid. In order to monitor the quality of the water in this saturated zone, a series of observation wells was installed. The location of the observation wells is shown in Figure 2, and specific data for the depths of the wells is given in Table 1.

There was little change in pH in the saturated zone during the spring and winter. During the summer the pH reached a high value of 8.8 in well 6A. Thereafter, there was a gradual decrease in the pH in all the wells, but it remained above pH 7.0 which was the average value of the sewage treatment plant effluent. During the fall the pattern was the same as during the summer but with less high pH values.

During all seasons the shallower wells indicated higher values of dissolved solids than the corresponding deeper wells. This indicates that the sewage containing higher dissolved solids than the ground water remained nearer the surface of the aquifer with the deeper sampling points more representative of the normal ground water. High dissolved solids were observed at wells 3 as influenced by the storage of the highway deicing salt at the town garage.

The shallower wells consistently had higher DO values than the deeper wells, with the lowest values occurring during the summer at 0.5 mg/l in wells 9 and 3D. There was a slight trend toward increasing DO with increased distance from the sand infiltration bed.

Redox potential measurements were only made during the spring of 1976 with values ranging between +100 and +150 mV. The lowest values were observed in the control wells which received no effluent from the sewage treatment plant.

There was a slight trend of decreasing chloride concentration with distance from the sand infiltration bed. Again, wells 3 showed the influence of the nearby highway deicing salt storage area.

There was little change in the organic nitrogen content of 2 mgN/l through the saturated portion of the soil system. However, the ammonia-nitrogen content was reduced from an average value of 4 mg/l to less than 0.1 mgN/l. During the summer there was a marked reduction in the nitrate content with values in well 2B of approximately 0.6 mgN/l. During the fall, winter and spring the nitrate values at well 2A ranged between 5 and 7 mgN/l. There appears to have been some microbially mediated conversion of the nitrate to gaseous forms of nitrogen during the summer.

In general the total phosphorus content was reduced to values less than 200 ug/l prior to emergence in the seepage at West Brook. The orthophosphate was in general less than 10 ugP/l with the lowest values of less than 0.2 ugP/l (the minimal detectable limit of the analytical method used) in well 2B.

DISCUSSION

The combined vertical and horizontal transport of the unchlorinated effluent from the Lake George Village Sewage Treatment Plant through the sand achieves the production of a highly purified effluent. There are no significant adverse effects upon ground water as indicated by the parameters of temperature, pH, alkalinity, coliforms, BOD, COD or soluble phosphorus. Whereas there are some increases in the total dissolved solids, the alkalinity and the chloride content of the ground water, these are within acceptable limits.

The only parameter of possible concern is the nitrate content which is in the range of 7 mgN/l in the seepage. This is close to the recommended drinking water standards of 10 mgN/l (7). It appears that the sand system is capable of further lowering this nitrate level primarily during the warmer seasons and at greater depths within the unsaturated zone. This is attributed to conversion of the nitrate ion to gaseous nitrogen which escapes from the aqueous system. Studies are presently being conducted to develop a method of creating conditions which would convert more nitrates to gaseous nitrogen without interfering with the phosphorus removal.

The Lake George Village Sewage Treatment Plant land application system has been successfully achieving the equivalent of tertiary treatment of domestic sewage since 1939. There are no indications that the system will not continue achieving this high degree of treatment for a long period of time. Thus, a land application system using sand can be considered to be a satisfactory method for providing tertiary treatment of wastewater.

ACKNOWLEDGEMENTS

The cooperation of Harold Gordon, Operator of the Lake George Village Tratement Plant, and his staff is greatly appreciated. This study was initiated with a small grant from the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory under Purchase Order BACA89-75-1265. The project was completed with support by EPA Grant R-803452-01-0 and a significant contribution by Rensselaer Polytechnic Institute.

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