

SMALL SCALE WASTE MANAGEMENT PROJECT

**Nitrogen Removal From Domestic Wastewater In
Unsewered Areas**

by

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NITROGEN REMOVAL FROM DOMESTIC WASTEWATER IN UNSEWERED AREAS

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ABSTRACT

This paper presents the results of an on-going field evaluation of several promising technologies for on-site nitrogen removal. A single field station with four parallel field-scale systems was built to provide side-by-side evaluations of recirculating sand filter-upflow anaerobic systems and peat filters. The wastewater from a correctional institution at this site receives septic tank processing followed by disposal through subsurface infiltration. A portion of the septic tank effluent has been diverted to the field station. The four parallel systems have been operated at conventional loading rates since November, 1992. The septic tank effluent has exhibited qualities typical of household wastewater. The anaerobic upflow-recirculating sand filter system has produced high quality effluent with low BOD and suspended solids. Total nitrogen concentrations below 15 mg/L as N were typically attainable. The peat filters produced high quality effluent with respect to BOD and solids but nitrogen removal to date has not been acceptable.

Keywords: Nitrogen Removal, Sand Filters, Peat Filters.

INTRODUCTION

Septic tank systems are known contributors of nitrate-nitrogen to the surficial groundwater. Concerns are growing that nitrate contamination of groundwater from on-site systems will raise groundwater concentration of nitrate-nitrogen above 10 mg/L, the current U.S. drinking water standard and the enforcement standard for groundwater established in the State of Wisconsin Administrative Code. High nitrate poses a potential threat to the health of those relying on shallow groundwater for drinking water. There is also concern for nitrogen enrichment of surface waters from contaminated groundwaters.

Currently, on-site systems are designed to prevent fecal indicator organisms from reaching the groundwater. Although nitrate contamination from on-site systems has been recognized for many years, there has been little concern for its significance until recently. Therefore, on-site nitrogen removal systems have not been fully developed and tested and little is known about the potential for these systems to be effective and affordable.

In 1990 a project was initiated by the Wisconsin Department of Industry, Labor and Human Relations to investigate methods of nitrogen removal from rural household wastewater. The objective of the project was to provide recommendations for nitrogen removal systems that would be capable of achieving specified removals under Wisconsin climatic conditions yet be affordable for the average rural homeowner.

EXPERIMENTAL ON-SITE SYSTEMS

The experimental field station was constructed at the Wisconsin Black River Falls Correctional Center (BRFCC) near Black River Falls, Wisconsin. The BRFCC is served by a conventional septic tank and subsurface infiltration. There was ample space for construction of the experimental system at this site. Furthermore, it provided a sufficient source of septic tank effluent and a means for final effluent disposal from the experimental system.

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The experimental field station consisted of four parallel treatment flowsheets including two sand filter systems and two peat filters (Fig. 1). The sand filter systems each included an anaerobic upflow filter (AUF), recirculation tank and sand filter plumbed such that the AUF could be by-passed. One system was designed to accept a chemical carbon source from an adjacent storage tank so as to provide flexibility in evaluating alternative flowsheets.

The entire station was designed to treat 670 gal/d. Septic tank effluent was pumped to a 780-gal source tank approximately 300 ft from the septic tank. Three pumps in the source tank delivered septic tank effluent to each of the two sand filter systems and both of the peat filters.

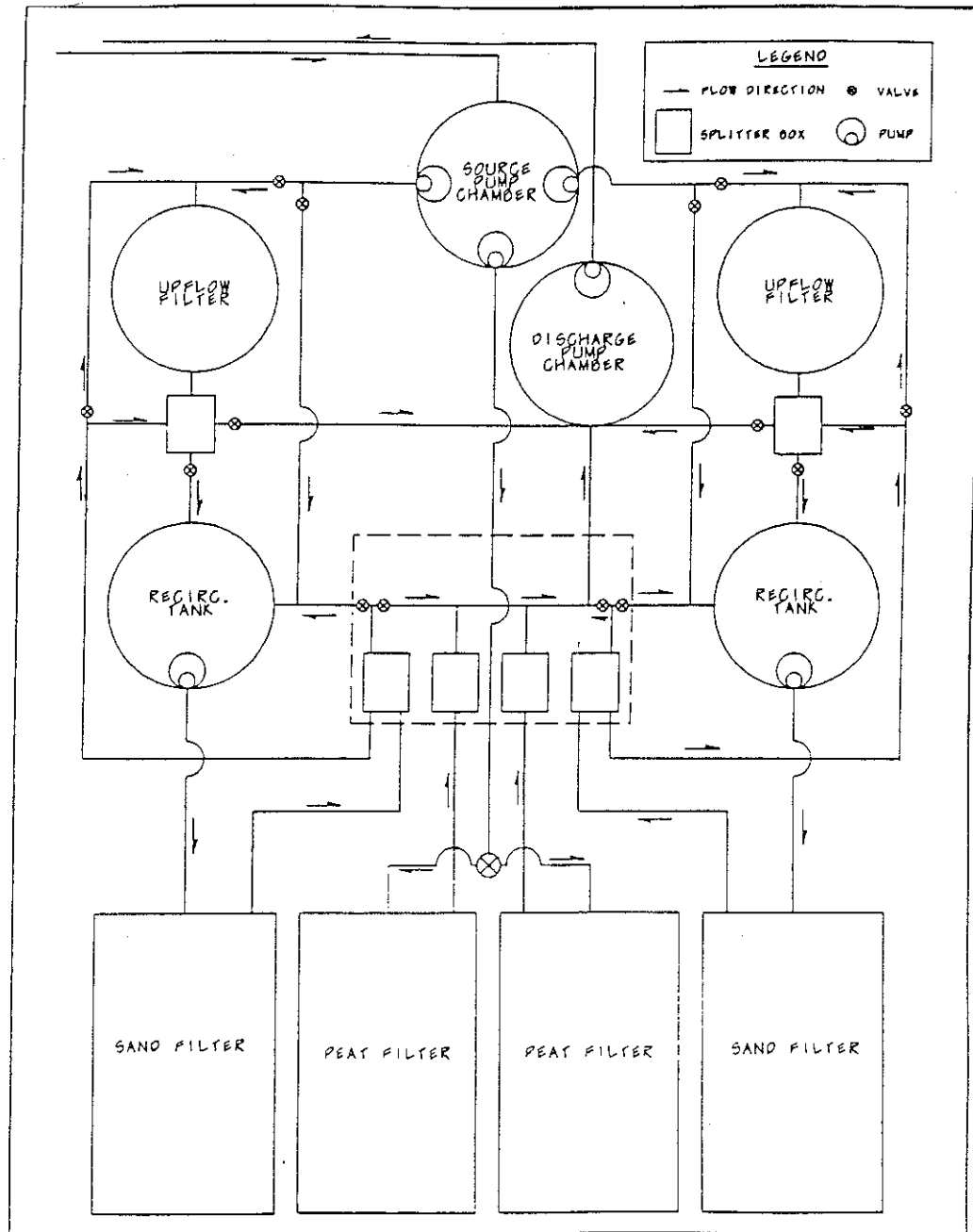


Figure 1. Layout of On-site Nitrogen Removal Research Station

Sand Filter Systems

For each sand filter system, several flowsheets were possible. Septic tank effluent could be directed to the AUF where it passed to the recirculation tank and sand filter. Sand filter effluent was subsequently recycled back to the AUF or was wasted depending on water depth in the recirculation tank. Pump rates from the recirculation tank were set to provide a 4:1 recycle ratio.

In a second flow arrangement, septic tank effluent was pumped directly to the recirculation tank and then to the sand filter. Sand filter effluent was then returned to the AUF preceded by an addition of methanol. AUF effluent was then discharged to waste (This flowsheet was not evaluated in this report). A third flowsheet directed septic tank effluent to recirculation tank and sand filter. Effluent from the sand filter was recycled back to the recirculation tank or could be wasted as in the first flowsheet.

Each AUF unit was a round concrete tank 4 ft deep and approximately 5.75 ft in diameter with a vertical wall provided so that one-half or all of the tank volume could be used. Initially, the units were filled with 40 in of No. 2 stone providing a porosity of approximately 35%. After almost one year of operation, the operating unit clogged with biomass and was taken out of service. The stone was replaced with 3.5-in-diameter hexagonal PVC packing with porosity of about 70% (Lantec Corp.). Because of the increased porosity only one-half of the tank volume was used with this new media.

Each of the two sand filters were 7 ft by 12 ft units containing 2 ft of sand overlying 4 in pea gravel and 8 in of No. 2 stone. Initially, locally available sand (washed concrete sand) with an effective size of 0.25 mm and uniformity coefficient of 5.2 was employed. After a short period of unsatisfactory operation due to surface clogging, the sand was replaced with No. 30 red flint sand with an effective size of 1.2 mm and uniformity coefficient of 1.24. Recirculation tanks preceding the filters each had a 780-gal capacity. Flow from the recirculation tanks was delivered once per hour for 5 min at a design flow of 1000 gal/d. This provided a recirculation flow ratio of 4:1. Flow of septic tank effluent from the source tank was pumped six times per day for a design flow of 250 gal/d to the system.

Peat Filters

Two peat filters were operated in parallel during the studies reported herein. Each of the two filters were 7 ft by 12 ft units. The units were filled with wet sphagnum peat that was placed in 8-in lifts each compacted to a density of between 6.2 and 9.4 lb/ft³. The No. 2 filter was filled with 4 ft of peat overlying 6 in of No. 2 stone. The lower 12 in of peat were flooded to provide an anoxic region below the aerobic upper layer. The No. 1 peat filter contained 3 ft of peat overlying 6 in of No. 2 stone. No flooding was provided in this unit but approximately 3 in of stone around the collection line were submerged with effluent. Septic tank effluent was dosed to each filter by means of an alternating valve in two 42-gallon doses per day (1 gal/ft²/d). Effluent was distributed over the filter surface through three 1.5-in-diameter PVC pipes containing 1/4-in orifices along the crowns. Eight-inch-diameter PVC pipes cut in half longitudinally were laid over these distribution pipes.

Sampling

Composite sampling was provided following the AUFs and sand filters using specially designed splitter/sampler trays. These tipping trays, equipped with counters, provided flow data as well as a means to collect samples. A tube connected to a port in the tray collected a portion of the wastewater each time the tray dumped. Septic tank effluent was sampled from the source tank pump discharge lines by means of a solenoid valve arrangement.

EXPERIMENTAL METHODS AND ANALYSIS

A shakedown period, in which several changes were made in equipment including replacement of the sand in both sand filter systems, occurred between June 26, 1992 and September 24, 1992. The first composite samples were collected from the four systems on November 17, 1992. Table 1 provides information on the initial design operating parameters for the four parallel flowsheets. During start-up, mixed liquor solids from an actively nitrifying-activated sludge plant were added to the source tank on several occasions to provide nitrifier seed.

Table 1. Design Operating Parameters—November 1992

| System | Flowsheet | Design Loading |
|-------------------|-----------|---|
| Sand Filter No. 1 | AUF-RSF | AUF: 9.6 gal/ft ² /d; 2.9 gal/ft ³ /d; θ = 0.9 days RSF: 12 gal/ft ² /d; R = 4:1 |
| Sand Filter No. 2 | RSF | RSF: 12 gal/ft ² /d; R = 4:1 |
| Peat Filter No. 1 | PF | PF: 1 gal/ft ² /d; Anoxic ~ 3 in |
| Peat Filter No. 2 | PF | PF: 1 gal/ft ² /d; Anoxic 12 in |

Composite samples were collected at approximately 2-week intervals, as described above, and analysis performed in the laboratory for nitrogen series, total phosphorous, BOD, TOC, alkalinity and solids series. All methods were performed in accordance with Standard Methods (APHA, 1992). Occasional samples were collected for fecal coliform and chlorides. *In-situ* sampling for ORP and temperature were provided by probes placed at selected elevations in the AUFs and sand filters. Field measurements of pH, DO and wastewater temperature were also collected at each visit.

RESULTS

General Operation

After the initial problems during start-up had been resolved, several other operational complications arose over the course of the study. These problems can be categorized in four areas: weatherization, ponding and clogging, pump and flow monitoring, and sampling. A brief description of problem and solution are given below.

During the very cold period in the winter months of 1992-93, temperatures fell below -20°F and remained low for days at a time. Several splitter/sample tray sampling outlets froze over this time, but addition of heat lamps resolved this problem. Difficulties with frozen pipes for sand filter No. 1 occurred on two occasions and were quickly resolved. There were no freezing problems with either peat filter system or sand filter system No. 2. Additional insulation was placed around piping to and from unit processes and earthen bunkers were increased in depth around filters, recirculation tanks and the control building.

Ponding in sand filter No. 2 was noted throughout the study. Note that this filter received septic tank effluent directly and apparently was loaded as high as 20 gal/d/ft² due to pump control difficulties. Although flow to the filter has been resolved, ponding continues to occur requiring raking at about 2-month intervals. No ponding was observed for sand filter No. 1. The AUF No. 1 began to clog with biomass in the Spring of 1993 and was eventually taken out of service in May of 1993. As described earlier, the No. 2 stone was replaced with a high-porosity PVC media. Because of its high porosity, only one-half of the AUF was used providing a hydraulic residence time of approximately 1 day. At that time, AUF No. 2 was also converted to plastic media. Sand filter system No. 2 was subsequently converted to a flow arrangement parallel to sand filter system No. 1 (AUF-RSF) with the same loading conditions. Both systems were operated in this mode commencing on July 21, 1993.

Numerous difficulties were encountered with the pump controls throughout the experimental system. Float controls were replaced in several instances and readjustments of the programmable logic controller (Allen Bradley) were made on several occasions. Some problems were encountered with splitter/sampler tray counters and with mechanical operation of the tipper trays due to accumulation of biomass on the outside of some trays. These problems have all been resolved.

Influent Characteristics

Results of the analyses of composite samples of the septic tank effluent (influent to all four treatment systems) appear in Table 2. The characteristics of the effluent are similar to those from individual homes with the exception of BOD which appears to be significantly higher than the average typically measured although well within the range of values reported (USEPA, 1980). The TKN ranged from 35 to 57 mg/L-N with an average of 45 mg/L; the BOD/TKN ratio ranged from 2.9 to 6.1, averaging about 4.2. The alkalinity and total dissolved solids concentration are typical of well water sources in central Wisconsin.

Sand Filter System No. 1

Results of the performance of sand filter system No. 1 (AUF-RSF) appear in Table 3 and a plot of influent and effluent nitrogen is presented in Fig. 2. During the course of operation to date, the system experienced several setbacks in performance, but overall, it was successful in removing nitrogen as well as BOD and suspended solids. Between February and April of 1993, the sand filter experienced two freezing events which significantly affected nitrification. Denitrification in the AUF was effective almost from start-up and continued through the cold winter months even during sand filter freezing problems. By May, the AUF had clogged, as described earlier, and was taken out of service. It was put back in service in July and within two weeks the system was performing in accordance with expectations. Nitrogen mass balances were performed throughout the sampling period. Nitrogen removal ranged from 13 to 90% over the 15-month period. Omitting intervals of time when the system malfunctioned, the average removal was approximately 75%. During this period of operation, the target flow rate to the system was not met, averaging 208 gal/d with a recirculation ratio of 5.5 to 1. A target effluent level of 10 mg/L total nitrogen was not achievable, however, with an average over the period of 15 mg/L N (excluding the May 14-July 23 period). Theoretical effluent nitrogen concentrations assuming complete nitrification/denitrification would be about 7 mg/L at this recycle ratio. It is likely, however, that available BOD to oxidizable nitrogen ratios may have been below ideal limits for complete denitrification. No DO was found in the AUF system and ORP measurements at 15-in and 30-in depths were typically in the range of -200 to -500 mV.

Sand Filter System No. 2

Results of performance of sand filter system No. 2 (RSF/AUF-RSF) appear in Table 4 and nitrogen results are depicted in Fig. 3. For the first 300 days of service (up to July 23, 1993), the system was operated as a recirculating sand filter alone. After that date, the AUF with plastic packing was placed in service. While the RSF system did not achieve the level of nitrogen removal demonstrated in sand filter system No. 2, it did produce consistently low BOD and suspended solids concentrations and showed promising reductions in nitrogen concentrations. Complete nitrification was not achieved from start-up to May 14, 1993. After that time, nitrification and significant denitrification produced total nitrogen values under 20 mg/L. Once the AUF was put on line (July 21, 1993), a dramatic effect was seen in effluent nitrogen concentrations. Results were parallel to those seen in sand filter system No. 1. From start-up through July, target flow rates to the filter were exceeded, averaging 340 gal/d. After July, flow rates were readjusted to approximate design flows at 250 gal/d.

Peat Filter Systems

Results of performance of the peat filter systems appear in Tables 5 and 6. Both systems operated through the period without incident. Effluent quality with respect to BOD and suspended solids was excellent throughout the test period. The effluent pH and alkalinity were below those in the sand filters, as expected from peat filter systems. A slight effluent tea color was noted throughout the 560 days of testing. Neither filter produced a high degree of nitrogen removal during the period. Note that peat filter No. 2 was designed to include an anoxic zone of peat to promote denitrification. As can be seen in Fig. 4, there was significant nitrification from start-up in this filter. Denitrification, however, was not prevalent in the system until the late summer and then appeared to decrease by early autumn. At best, about 40% nitrogen removals were estimated from this unit.

In peat filter No. 1, which was designed with a minimal anoxic zone in the underdrain system, nitrogen removal was even poorer. In fact, it appeared that significant nitrogen release occurred between April and July, 1993. Reasons are not clear at this time although similar results have

Table 2. Influent Wastewater Characteristics.

| DATE | DAY | Type | pH | Temp(°C) | ALK. | TKN | NH4-N | NO3-N | lot N | TOC | FECAL | CL- | TOTAL P | BOODS | TSS | TDS | FSS | VSS | FDS | VDS |
|-----------|-----|------|-----|----------|------|-----|-------|-------|-------|-----|-------|-----|---------|-------|-----|-----|-----|-----|-----|-----|
| 12-Jan-93 | 216 | C | 6.8 | 11.9 | 173 | 38 | 27 | 1 | 39 | 42 | | | 7.3 | 118 | 26 | 244 | 0 | 26 | 220 | 24 |
| 21-Jan-93 | 225 | C | 7.0 | 12.0 | 210 | 45 | 33 | 1 | 46 | 30 | | | 6.4 | 131 | 42 | 256 | 0 | 42 | 182 | 74 |
| 28-Jan-93 | 232 | C | 6.9 | 13.0 | 290 | 44 | 36 | 1 | 45 | 54 | | | 9.4 | 143 | 27 | 303 | 0 | 27 | 164 | 139 |
| 4-Feb-93 | 239 | C | 7.2 | 14.0 | | 49 | 38 | 1 | 50 | | | | 8.3 | 31 | 291 | 0 | 31 | 165 | 126 | |
| 11-Feb-93 | 246 | C | 6.7 | 14.0 | 187 | | 30 | 1 | 107 | | | | 6.8 | 204 | | | | | | |
| 26-Feb-93 | 261 | C | 6.5 | 9.0 | 213 | 44 | 33 | 1 | 45 | 115 | | | 8.6 | | 22 | 372 | 0 | 22 | 165 | 207 |
| 4-Mar-93 | 267 | C | | 12.0 | | 48 | 36 | 1 | 49 | 74 | | | | | 183 | 11 | 346 | 0 | 11 | 201 |
| 18-Mar-93 | 281 | C | 7.2 | 9.0 | 283 | 47 | 36 | 1 | 48 | 103 | | | | | 147 | 14 | 367 | 0 | 14 | 255 |
| 25-Mar-93 | 288 | C | 6.7 | 12.0 | 233 | 41 | 34 | 1 | 42 | 74 | | | 7.2 | 142 | | | | | | |
| 8-Apr-93 | 302 | C | 7.5 | 14.0 | | 49 | 30 | 1 | 50 | 90 | | | 7.5 | | 57 | 338 | 4 | 53 | 187 | 151 |
| 22-Apr-93 | 316 | C | 7.0 | 14.0 | 221 | 50 | 33 | 1 | 51 | 100 | | | 6.3 | 145 | 49 | 323 | 0 | 49 | 221 | 102 |
| 6-May-93 | 330 | G | 6.6 | 19.0 | | 48 | 32 | 1 | 49 | | 15.0 | 44 | 5.9 | | 80 | 338 | 1 | 79 | 187 | 151 |
| 14-May-93 | 338 | C | | 19.0 | 220 | 44 | 32 | 1 | 45 | 109 | | | 6.4 | 163 | | | | | | |
| 20-May-93 | 344 | C | 7.0 | 17.0 | 220 | 40 | 29 | 0 | 40 | | | | 6.5 | | 53 | 287 | 0 | 53 | 121 | 166 |
| 4-Jun-93 | 359 | C | 6.9 | | 236 | 50 | 39 | 1 | 51 | | | | 7.7 | 179 | 61 | 500 | 11 | 50 | 228 | 272 |
| 9-Jun-93 | 364 | C | | 19.0 | | 45 | 38 | 0 | 45 | 132 | 2.4 | 53 | 6.7 | 165 | 58 | 488 | 0 | 58 | 242 | 276 |
| 18-Jun-93 | 373 | C | 7.2 | 18.0 | | 46 | 37 | 0 | 46 | | | | 8.7 | 165 | | | | | | |
| 25-Jun-93 | 380 | C | 6.9 | 23.0 | 170 | 35 | 24 | 0 | 35 | | | | 39 | 46 | 43 | 202 | 2 | 41 | | |
| 9-Jul-93 | 394 | C | 7.0 | 23.0 | 228 | 42 | 34 | 0 | 42 | | | | 66 | 7.3 | 207 | 76 | 256 | 0 | 76 | 121 |
| 16-Jul-91 | 401 | C | 7.2 | 21.0 | 252 | 46 | 38 | 0 | 46 | | | | 8.7 | 145 | 129 | 357 | 18 | 111 | 244 | 113 |
| 23-Jul-93 | 408 | C | 7.1 | 24.0 | | 38 | 30 | 0 | 38 | | | | 65 | 7.6 | 144 | 89 | 335 | 5 | 34 | 220 |
| 6-Aug-93 | 422 | C | 6.9 | 22.0 | 238 | 44 | 38 | 0 | 44 | | | | 64 | 5.5 | 176 | | | | | |
| 12-Aug-93 | 428 | C | 6.6 | 24.0 | 209 | 40 | 33 | 0 | 40 | | | | 65 | 5.4 | 214 | 80 | 395 | 7 | 73 | 270 |
| 28-Aug-93 | 442 | C | 6.7 | | | 51 | 39 | 0 | 51 | | | | 5.8 | 270 | 69 | 387 | 15 | 54 | 200 | 187 |
| 4-Sep-93 | 451 | C | 6.8 | 22.0 | 214 | 47 | 37 | 0 | 47 | | | | 5.4 | 190 | | 508 | | | 189 | 319 |
| 11-Sep-93 | 458 | G | 7.0 | 18.0 | 225 | 42 | 40 | 0 | 42 | | | | 69 | 7.5 | 156 | | | | | |
| 24-Sep-93 | 471 | C | 6.7 | | 207 | | 42 | 0 | | | | | 68 | 7.5 | 266 | 39 | 413 | 1 | 38 | 213 |
| 5-Oct-93 | 482 | C | 6.7 | 16.5 | 210 | 55 | 38 | 0 | 55 | | | | 65 | 7.8 | 274 | 56 | 338 | 4 | 52 | 207 |
| 15-Oct-93 | 492 | C | 6.6 | 11.0 | 204 | 48 | 38 | 0 | 48 | | | | 64 | | 52 | 334 | 2 | 50 | 138 | 196 |
| 26-Oct-93 | 503 | C | 6.7 | 16.0 | 217 | 48 | 39 | 0 | 48 | | 4.8 | 49 | 8.0 | 279 | 64 | 261 | 1 | 63 | 197 | 64 |
| 5-Nov-93 | 513 | C | 6.7 | 13.0 | | 52 | 41 | 0 | 52 | | | | 56 | 7.9 | 28 | 293 | 0 | 28 | 144 | 149 |
| 13-Nov-93 | 521 | C | 6.7 | 12.0 | 108 | 50 | 30 | 0 | 50 | | | | 70 | 9.6 | 382 | 32 | 358 | 1 | 31 | 310 |
| 30-Nov-93 | 538 | C | 6.9 | 12.0 | 237 | 49 | 40 | 1 | 50 | | 15.0 | 61 | | 300 | | | | | | 48 |
| 11-Dec-93 | 549 | C | 7.1 | 11.0 | 273 | 52 | 41 | 0 | 52 | | | | | 241 | 33 | 392 | 0 | 33 | 250 | 142 |
| 22-Dec-93 | 560 | C | 7.0 | 10.0 | 261 | 57 | 48 | 1 | 58 | | | | | | | | | | | |
| AVG | | | 7 | 16 | 221 | 46 | 36 | 0 | 47 | 86 | 9 | 60 | 7 | 193 | 50 | 344 | 3 | 46 | 202 | 149 |
| ST. DEV | | | 0 | 5 | 37 | 5 | 5 | 1 | 5 | 31 | 7 | 10 | 1 | 60 | 26 | 76 | 5 | 22 | 46 | 68 |

Note: all units as mg/L except pH, temperature (°C) and fecal coliforms (mpn/100 ml)

Note: all units as mg/L except pH, temperature (°C) and fecal coliforms (x10E6 colonies/100mL)

Table 3. Sand Filter System No. 1 - Effluent Concentrations (mg/L).

| DATE | DAY | Type | pH | Temp(°C) | ALK. | TKN | NH4-N | NO3-N | Total N | TOC | FECAL | CL- | TOTAL P | BOODS | TSS | TDSS | FBS | VSS | FDS | VDS | |
|--------------------------------------|-----|------|-----|----------|------|-----|-------|-------|---------|-----|-------|-----|---------|-------|-----|------|-----|-----|-----|-----|-----|
| 12-Jan-93 | 109 | C | 6.6 | 3.1 | 72 | 3 | 1 | 12 | 15 | 12 | | | 5.7 | 5 | 0 | 305 | 0 | 0 | 267 | 36 | |
| 21-Jan-93 | 118 | C | 6.7 | 2.0 | 82 | 4 | 2 | 12 | 16 | 13 | | | 5.2 | 8 | 0 | 292 | 0 | 0 | 190 | 102 | |
| 28-Jan-93 | 125 | C | 6.8 | 3.0 | 85 | 6 | 4 | 9 | 15 | 18 | | | 7.0 | 11 | 0 | 357 | 0 | 0 | 157 | 100 | |
| 4-Feb-93 | 132 | C | | Frozen | | | | | | | | | | | | | | | | | |
| 11-Feb-93 | 139 | C | 6.6 | 5.0 | 79 | | 4 | 15 | | 21 | | | 5.7 | 10 | | | | | | | |
| 26-Feb-93 | 154 | C | 6.8 | 2.0 | 153 | 21 | 14 | 6 | 27 | 55 | | | 6.0 | | 0 | 285 | 0 | 0 | 168 | 117 | |
| 4-Mar-93 | 160 | C | | 2.0 | | 25 | 19 | 3 | 28 | 60 | | | | 24 | 4 | 269 | 0 | 4 | 153 | 116 | |
| 18-Mar-93 | 174 | C | 7.2 | Frozen | | | | | | | | | | | | | | | | | |
| 25-Mar-93 | 181 | C | 7.0 | 3.0 | 129 | 7 | 7 | 8 | 15 | 38 | | | 6.6 | 19 | | | | | | | |
| 8-Apr-93 | 195 | C | 7.2 | 4.0 | | 18 | 12 | 9 | 27 | 50 | | | 6.3 | | 14 | 270 | 0 | 14 | 186 | 79 | |
| 22-Apr-93 | 209 | C | 5.6 | 5.0 | 205 | 18 | | 2 | | 75 | | | 5.7 | 31 | 33 | 305 | 0 | 33 | 232 | 73 | |
| 6-May-93 | 223 | G | 6.7 | 11.0 | | 9 | 0 | 8 | 17 | | >1000 | 47 | 6.3 | 3 | 0 | 340 | 0 | 0 | 265 | 75 | |
| AUF #1 taken off-line | | | | | | | | | | | | | | | | | | | | | |
| 14-May-93 | 231 | C | | 14.0 | 56 | 1 | 1 | 45 | 46 | 14 | | | 4.9 | 2 | | | | | | | |
| 20-May-93 | 237 | C | 6.6 | 12.0 | 38 | 5 | 0 | 32 | 37 | | | | 4.5 | | 0 | 370 | 0 | 0 | 223 | 142 | |
| 4-Jun-93 | 252 | C | 6.7 | | 40 | 2 | 0 | 33 | 35 | | 1500 | 51 | 4.6 | 3 | | | | | | | |
| 9-Jun-93 | 257 | C | | 19.0 | | | | | | 108 | | | 4.8 | 2 | 0 | 518 | 0 | 0 | 308 | 210 | |
| 16-Jun-93 | 266 | C | 6.8 | 18.0 | | 2 | 0 | 31 | 33 | 18 | | | 5.7 | 4 | | | | | | | |
| 25-Jun-93 | 279 | C | 6.7 | 19.0 | 41 | 3 | 0 | 27 | 30 | | | | 5.0 | 5.2 | 3 | 16 | 329 | 5 | 11 | | |
| 9-Jul-93 | 287 | G | 6.9 | 19.0 | | 116 | 5 | 2 | 5 | 10 | | | 6.2 | 4 | 8 | 170 | 0 | 8 | 108 | 84 | |
| 16-Jul-93 | 294 | G | 7.0 | 19.0 | 93 | | 3 | | | | | | 5.5 | 5.3 | 23 | 517 | 9 | 14 | 320 | 197 | |
| AUF #1 placed on-line with new media | | | | | | | | | | | | | | | | | | | | | |
| 23-Jul-93 | 301 | C | 7.4 | 20.0 | | 29 | 20 | 0 | 29 | | | | 6.4 | 6.8 | 40 | 84 | 288 | 84 | 20 | 208 | 82 |
| 6-Aug-93 | 315 | C | 7.5 | 18.0 | 48 | 1 | 0 | 8 | 9 | | | | 6.1 | 4.2 | 3 | | | | | | |
| 12-Aug-93 | 321 | C | 7.6 | 21.0 | 93 | 3 | 0 | 5 | 8 | | | | 4.0 | 2 | 38 | 296 | 24 | 12 | 264 | 32 | |
| 26-Aug-93 | 335 | C | 7.2 | | | 4 | 0 | 2 | 6 | | | | 4.5 | 2 | 5 | 292 | 3 | 2 | 187 | 105 | |
| 4-Sep-93 | 344 | G | 7.5 | 22.0 | 61 | 5 | 0 | | | | | | 4.8 | 2 | | | | | | | |
| 11-Sep-93 | 351 | G | 6.6 | 18.0 | 89 | | | | | | | | 6.3 | 5.6 | | | | | | | |
| 24-Sep-93 | 358 | C | 7.2 | | | 129 | 9 | 6 | 11 | 20 | | | 6.8 | 6.2 | 9 | 4 | 330 | 2 | 2 | 211 | 120 |
| 5-Oct-93 | 369 | C | 7.2 | 12.5 | 93 | 4 | 1 | 8 | 12 | | | | 6.6 | 6.6 | 7 | 3 | 523 | 2 | 1 | 264 | 259 |
| 15-Oct-93 | 379 | C | 7.2 | 10.0 | 95 | 3 | 1 | 7 | 10 | | | | 6.1 | | 6 | 250 | 0 | 6 | 176 | 74 | |
| 26-Oct-93 | 390 | G | 6.9 | 9.0 | 102 | 3 | 1 | 7 | 10 | 102 | | | 4.80 | 5.2 | 7 | 3 | 298 | 0 | 3 | 156 | 53 |
| 5-Nov-93 | 400 | G | 6.8 | 7.0 | | 1 | 0 | 10 | 11 | | | | 5.2 | 7.0 | 1 | 295 | 0 | 1 | 185 | 110 | |
| 13-Nov-93 | 408 | C | 6.9 | 8.0 | 118 | 4 | | 8 | | | | | 5.8 | 7.2 | 10 | 11 | 310 | 4 | 7 | 293 | 17 |
| 30-Nov-93 | 425 | C | 7.6 | 5.0 | 98 | 3 | 0 | 8 | 11 | | | | 4.80 | 6.0 | 7 | | | | | | |
| 11-Dec-93 | 436 | C | 4.0 | | | 4 | 0 | 8 | 12 | | | | | | 5 | 6 | 333 | 5 | 1 | 260 | 73 |
| 22-Dec-93 | 447 | C | 7.1 | 4.0 | 91 | 3 | 1 | 10 | 13 | | | | | | | | | | | | |
| AVG | | | | | | | | | | | | | | | | | | | | | |
| ST. DEV | | | | | | | | | | | | | | | | | | | | | |

Note: all units as mg/l except pH, temperature (°C) and fecal coliforms (colony forming units (cfu)).

Note: all units as mg/L except pH, temperature (°C) and fecal coliforms (colonies/100mL)

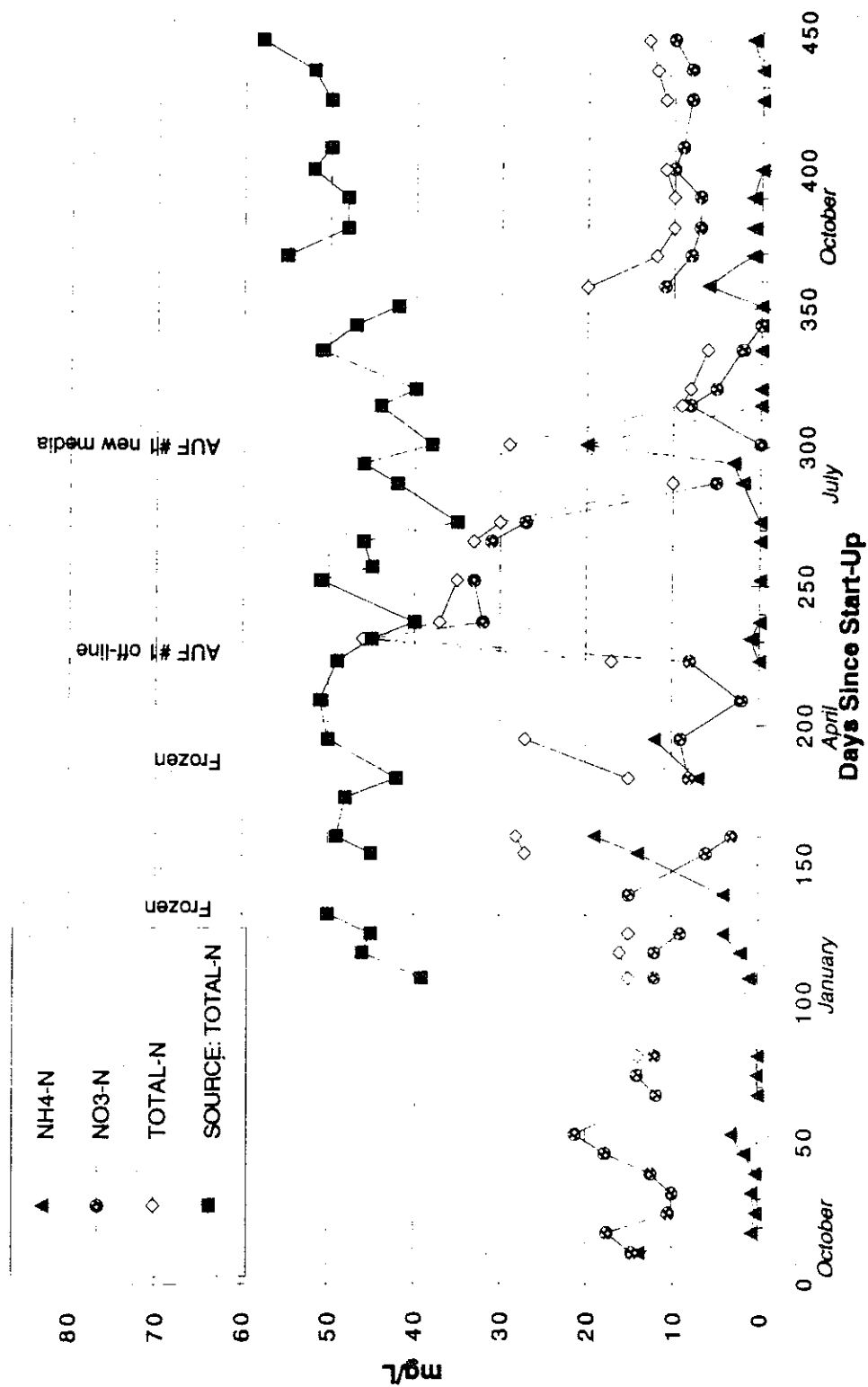


Figure 2. Sand Filter No. 1 Nitrogen.

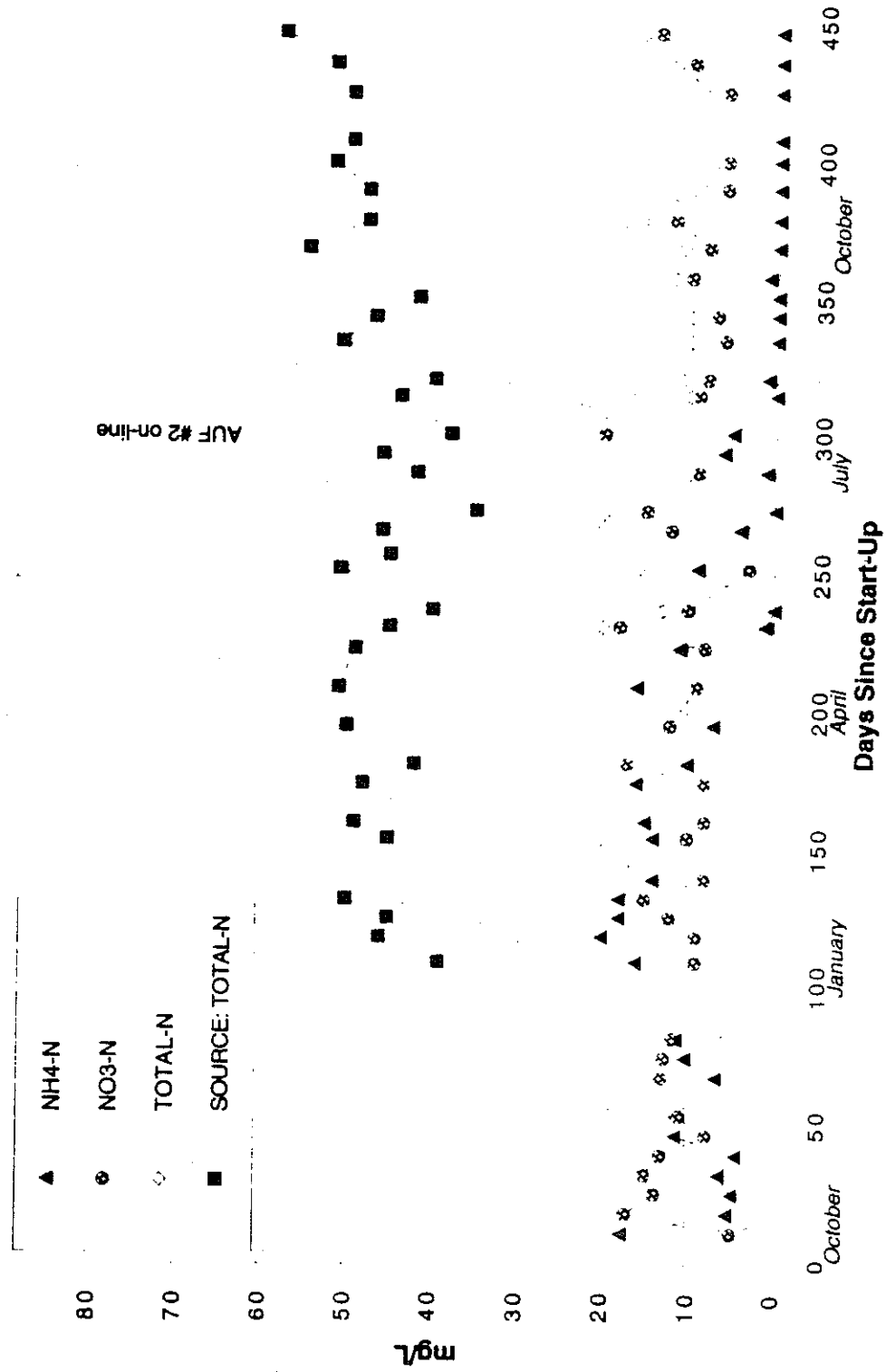


Figure 3. Sand Filter No. 2 Nitrogen.

Table 4. Sand Filter System No. 2 - Effluent Concentrations (mg/L).

| DATE | DAY | Type | pH | Temp(°C) | ALK. | TKN | NH4-N | NO3-N | total N | TOC | FECAL | CL- | TOTAL P | BOO5 | TSS | TDS | FSS | VSS | RD6 | VDS | |
|--------------------------------------|-----|------|-----|----------|------|-----|-------|-------|---------|-----|-------|-----|---------|------|-----|-----|-----|-----|-----|-----|-----|
| 12-Jan-93 | 109 | C | 6.7 | 5.2 | 145 | 23 | 16 | 9 | 32 | 25 | | | 7.6 | 15 | 0 | 263 | 0 | 0 | 205 | 58 | |
| 21-Jan-93 | 118 | C | 6.8 | 4.0 | 162 | 26 | 20 | 9 | 35 | 19 | | | 7.5 | 12 | 0 | 284 | 0 | 0 | 174 | 120 | |
| 28-Jan-93 | 125 | C | 6.7 | 4.0 | 133 | 22 | 18 | 12 | 34 | 25 | | | 8.0 | 8 | 1 | 261 | 0 | 1 | 159 | 102 | |
| 4-Feb-93 | 132 | C | 7.2 | 4.0 | | 25 | 18 | 15 | 40 | 40 | | | 5.8 | | 45 | 304 | 3 | 42 | 177 | 127 | |
| 11-Feb-93 | 139 | C | 6.9 | | 123 | | 14 | 8 | | 33 | | | 5.7 | 16 | | | | | | | |
| 26-Feb-93 | 154 | C | 6.3 | 3.0 | 149 | 10 | 14 | 10 | 20 | 28 | | | 7.0 | | 0 | 279 | 0 | 0 | 133 | 146 | |
| 4-Mar-93 | 160 | C | | 2.0 | | 20 | 15 | 8 | 28 | 61 | | | | | 8 | 0 | 350 | 0 | 0 | 199 | 151 |
| 18-Mar-93 | 174 | C | 7.0 | 3.0 | 180 | 23 | 16 | 8 | 31 | 25 | | | | | 7 | 0 | 330 | 0 | 0 | 238 | 92 |
| 25-Mar-93 | 181 | C | 6.6 | 5.0 | 101 | 10 | 10 | 17 | 27 | 21 | | | 6.8 | 5 | | | | | | | |
| 8-Apr-93 | 195 | C | 6.9 | 7.0 | | 13 | 7 | 12 | 25 | 20 | | | 7.2 | | 0 | 283 | 0 | 0 | 187 | 96 | |
| 22-Apr-93 | 209 | C | 6.4 | 6.0 | 240 | 22 | 16 | 9 | 31 | 34 | | | 5.9 | 14 | 7 | 290 | 0 | 7 | 215 | 75 | |
| 6-May-93 | 223 | G | 6.5 | 14.0 | | 14 | 11 | 6 | 22 | | 610 | 51 | 6.1 | 21 | 8 | 266 | 1 | 7 | 166 | 100 | |
| 14-May-93 | 231 | C | | 16.0 | 61 | 2 | 1 | 16 | 20 | 19 | | | 4.4 | 6 | | | | | | | |
| 20-May-93 | 237 | C | 6.2 | 13.0 | 74 | 3 | 0 | 10 | 13 | | | | 5.1 | | 3 | 412 | 1 | 2 | 126 | 288 | |
| 4-Jun-93 | 252 | C | 6.9 | | 193 | 13 | 9 | 3 | 16 | | | | 5.7 | 9 | 7 | 275 | 2 | 5 | 231 | 144 | |
| 9-Jun-93 | 257 | C | | 14.0 | | 23 | | | | | 70000 | 52 | 5.7 | 17 | 0 | 411 | 0 | 0 | 256 | 155 | |
| 16-Jun-93 | 266 | C | 7.0 | 16.0 | | 9 | 4 | 12 | 21 | 20 | | | 3.0 | 4 | | | | | | | |
| 25-Jun-93 | 273 | C | 6.4 | 20.0 | 59 | 4 | 0 | 15 | 19 | | 44 | | 2.0 | 2 | 2 | 271 | 0 | 2 | | | |
| 9-Jul-93 | 287 | C | 6.9 | 20.0 | 100 | 4 | 1 | 9 | 13 | 14 | | | 4.7 | 3 | 12 | 181 | 0 | 12 | 98 | 81 | |
| 16-Jul-93 | 294 | G | 6.6 | 20.0 | 90 | | 6 | | | | 57 | | 2.4 | 107 | 38 | 532 | 17 | 21 | 364 | 168 | |
| AUF #2 placed on-line with new media | | | | | | | | | | | | | | | | | | | | | |
| 23-Jul-93 | 301 | C | 6.9 | 21.0 | | 8 | 5 | 20 | 28 | | 54 | | 3.3 | 8 | 20 | 288 | 0 | 20 | 178 | 110 | |
| 6-Aug-93 | 315 | G | 6.8 | 20.0 | 49 | 1 | 0 | 9 | 10 | | 62 | | 4.6 | | | | | | | | |
| 12-Aug-93 | 321 | C | 7.2 | 21.0 | 92 | 3 | 1 | 8 | 11 | | 68 | | 3.3 | 2 | 6 | 300 | 2 | 4 | 237 | 63 | |
| 26-Aug-93 | 335 | C | 7.2 | | | 4 | 0 | 6 | 10 | | | | 4.4 | 6 | 7 | 288 | 1 | 6 | 207 | 81 | |
| 4-Sep-93 | 344 | C | 7.5 | 19.0 | 91 | 3 | 0 | 7 | 10 | | | | 4.6 | 3 | | 341 | | | 213 | 128 | |
| 11-Sep-93 | 351 | G | 7.0 | 17.0 | 74 | | 0 | | | | 61 | | 5.9 | 4 | | | | | | | |
| 24-Sep-93 | 356 | C | 7.3 | | 101 | 2 | 1 | 10 | 12 | | 68 | | 5.4 | 4 | 1 | 304 | 0 | 1 | 192 | 112 | |
| 5-Oct-93 | 369 | C | 7.1 | 12.5 | 101 | 3 | 0 | 8 | 11 | | 66 | | 5.8 | 4 | 11 | 435 | 4 | 7 | 247 | 188 | |
| 15-Oct-93 | 379 | C | 7.2 | 11.0 | 98 | 4 | 0 | 12 | 16 | | 62 | | | 2 | 6 | 227 | 1 | 5 | 137 | 90 | |
| 26-Oct-93 | 390 | C | 7.4 | 10.0 | 101 | 3 | 0 | 6 | 9 | | 850 | | 5.1 | 5.8 | 2 | 222 | 2 | 5 | 181 | 61 | |
| 5-Nov-93 | 400 | C | 7.5 | 7.0 | | 1 | 0 | 6 | 7 | | 52 | | 5.7 | | 4 | 279 | 0 | 4 | 195 | 84 | |
| 13-Nov-93 | 408 | C | 7.1 | 7.0 | 118 | | | | | | 56 | | 7.1 | 3 | 13 | 289 | 9 | 4 | 283 | 16 | |
| 30-Nov-93 | 425 | C | 7.5 | 6.0 | 109 | 2 | 0 | 6 | 8 | | 700 | | | 6 | | | | | | | |
| 11-Dec-93 | 436 | C | 7.6 | 5.0 | 95 | 2 | 0 | 10 | 12 | | | | | | | | | | | | |
| 22-Dec-93 | 447 | C | | 4.0 | | 2 | 0 | 14 | 16 | | | | | | | | | | | | |
| AVG | | | 7 | 11 | 114 | 10 | 6 | 10 | 20 | 27 | 18040 | 57 | 5 | 7 | 8 | 307 | 2 | 6 | 199 | 113 | |
| ST DEV | | | 0 | 7 | 45 | 9 | 7 | 4 | 9 | 12 | 34640 | 7 | 2 | 5 | 11 | 73 | 4 | 9 | 56 | 53 | |

Note: all units as mg/L except pH, temperature (°C) and fecal coliforms (colonies/100ml)

Note: all units as mg/L except pH, temperature (°C) and fecal coliforms (colonies/100ml)

Table 5. Peat Filter No. 1 - Effluent Concentrations (mg/L).

| DATE | DAY | Type | pH | Temp(°C) | ALK. | TKN | NH4-N | NO3-N | TOT-N | DOC | FECAL | CL- | TOTAL P | BOO5 | TSS | TDS | FSS | VSS | FD5 | VDS |
|-----------|-----|------|------|----------|------|-----|-------|-------|-------|-----|-------|-----|---------|------|-----|-----|-----|-----|-----|-----|
| 12-Jan-93 | 109 | C | 5.9 | 2.1 | 12 | 12 | 9 | 5 | 17 | 42 | | | 7.9 | 4 | 2 | 210 | 0 | 2 | 153 | 57 |
| 21-Jan-93 | 118 | C | 5.9 | 2.0 | 13 | 12 | 10 | 6 | 18 | 42 | | | 7.7 | 3 | 0 | 255 | 0 | 0 | 112 | 143 |
| 26-Jan-93 | 125 | C | 6.4 | 2.0 | 13 | 12 | 10 | 6 | 18 | 45 | | | 7.9 | 2 | 0 | 222 | 0 | 0 | 108 | 114 |
| 4-Feb-93 | 132 | C | 5.7 | 2.0 | 13 | 13 | 10 | 6 | 19 | 50 | | | 7.2 | | 0 | 232 | 0 | 0 | | |
| 11-Feb-93 | 139 | C | 6.2 | 2.0 | 11 | 10 | 10 | 7 | 53 | | | | 7.5 | 3 | | | | | | |
| 26-Feb-93 | 154 | C | 6.1 | 1.0 | 20 | 7 | 11 | 8 | 15 | 54 | | | 7.4 | | 0 | 266 | 0 | 0 | 86 | 180 |
| 4-Mar-93 | 160 | C | 6.3 | 1.5 | 29 | 20 | 12 | 9 | 29 | 49 | | | 4.0 | 4 | 0 | 291 | 0 | 0 | 155 | 136 |
| 18-Mar-93 | 174 | C | 5.9 | 2.0 | 25 | 13 | 13 | 9 | 22 | 48 | | | 7.4 | 3 | 0 | 285 | 0 | 0 | 179 | 106 |
| 26-Mar-93 | 181 | C | 5.7 | 3.0 | 27 | 17 | 13 | 12 | 29 | 60 | | | 7.9 | | 0 | 291 | 0 | 0 | 142 | 149 |
| 8-Apr-93 | 195 | C | 4.8 | 5.0 | 27 | 17 | 14 | 19 | 36 | 61 | | | 7.9 | 2 | 0 | 348 | 0 | 0 | 193 | 153 |
| 22-Apr-93 | 209 | C | 5.4 | 10.5 | 33 | 23 | 20 | 33 | 58 | | <10 | 51 | 7.5 | 3 | 0 | 422 | 0 | 0 | 149 | 273 |
| 6-May-93 | 223 | C | 12.0 | 12.0 | 33 | 27 | 23 | 43 | 70 | 92 | | | 7.3 | 2 | | | | | | |
| 14-May-93 | 231 | C | 5.7 | 11.0 | 29 | 25 | 24 | 46 | 71 | 83 | | | 7.0 | | 2 | 414 | 0 | 2 | 145 | 274 |
| 20-May-93 | 237 | C | 5.8 | 12.0 | 36 | 35 | 31 | 67 | 102 | | | | 6.8 | 2 | 5 | 702 | 2 | 3 | 239 | 463 |
| 4-Jun-93 | 252 | C | | | | 40 | | | | 66 | 9 | 53 | 6.8 | 2 | 2 | 758 | 0 | 2 | 326 | 432 |
| 9-Jun-93 | 257 | C | 5.9 | 17.0 | | 27 | 31 | 75 | 102 | 71 | | | 7.3 | 1 | | | | | | |
| 18-Jun-93 | 266 | C | 5.5 | 18.0 | 13 | 28 | 29 | 77 | 105 | | | 53 | 7.5 | 2 | 7 | 589 | 0 | 7 | | |
| 25-Jun-93 | 273 | C | 5.6 | 19.0 | 20 | 27 | 22 | 61 | 88 | 82 | | | 7.4 | 1 | 3 | 424 | 0 | 3 | 132 | 292 |
| 9-Jul-93 | 287 | G | 5.9 | 21.0 | 16 | 25 | 24 | 76 | 101 | | | 54 | 6.3 | 2 | 10 | 765 | 0 | 10 | 314 | 451 |
| 16-Jul-93 | 294 | G | 6.0 | 20.0 | 21 | 22 | 19 | 65 | 87 | | | 58 | 6.0 | 1 | 6 | 539 | 0 | 6 | 221 | 318 |
| 23-Jul-93 | 301 | C | 5.8 | 20.0 | 21 | 21 | 13 | 52 | 73 | | | 60 | 5.7 | | | | | | | |
| 6-Aug-93 | 315 | C | 5.7 | 21.0 | 22 | 14 | 11 | 28 | 42 | | | 66 | 5.4 | 1 | 2 | 608 | 0 | 2 | 291 | 315 |
| 12-Aug-93 | 321 | C | 5.8 | | | 14 | 9 | 24 | 38 | | | | 5.7 | 2 | 0 | 578 | 0 | 0 | 252 | 326 |
| 26-Aug-93 | 335 | C | 6.0 | 20.0 | 33 | 14 | 7 | 40 | 54 | | | | 5.9 | 2 | | 652 | | 254 | 398 | |
| 4-Sep-93 | 344 | C | 7.8 | 14.0 | 80 | 8 | 5 | 32 | 40 | | | 60 | 7.7 | | | | | | | |
| 11-Sep-93 | 351 | G | 6.4 | | 45 | 10 | 6 | 38 | 48 | | | 64 | 7.0 | 3 | 2 | 626 | 0 | 2 | 252 | 374 |
| 24-Sep-93 | 364 | C | 6.2 | 14.0 | 32 | 9 | 4 | 34 | 43 | | | 66 | 6.8 | 3 | 3 | 281 | 1 | 2 | 233 | 48 |
| 5-Oct-93 | 375 | C | 6.1 | 11.5 | 28 | 7 | 4 | 35 | 42 | | | 66 | | | 2 | 438 | 0 | 2 | 219 | 219 |
| 15-Oct-93 | 385 | C | 6.1 | 11.0 | 20 | 5 | 3 | 37 | 42 | | 19 | 53 | 7.2 | 2 | 2 | 352 | 0 | 2 | 202 | 150 |
| 26-Oct-93 | 396 | C | 6.0 | 8.0 | 18 | 7 | 3 | 30 | 37 | | | 56 | 8.1 | 3 | 9 | 410 | 4 | 5 | 288 | 122 |
| 5-Nov-93 | 406 | C | 5.7 | 6.0 | 12 | 6 | 3 | 36 | 42 | | 90 | 59 | | 3 | | | | | | |
| 13-Nov-93 | 414 | C | 5.8 | 5.0 | 12 | 5 | 3 | 39 | 44 | | | | | | 4 | 454 | 2 | 2 | 246 | 208 |
| 30-Nov-93 | 431 | C | 5.5 | 4.0 | 9 | 7 | 2 | 36 | 43 | | | | | | | | | | | |
| 11-Dec-93 | 442 | C | | | | | | | | | | | | | | | | | | |
| 22-Dec-93 | 453 | C | | | | | | | | | | | | | | | | | | |
| AVG | | | 6 | 10 | 24 | 16 | 12 | 34 | 50 | 60 | 39 | 58 | 7 | 2 | 2 | 439 | 0 | 11 | 210 | 230 |
| ST. DEV | | | 0 | 7 | 15 | 8 | 9 | 22 | 27 | 16 | 44 | 5 | 1 | 1 | 3 | 170 | 1 | 49 | 77 | 121 |

Note: all units as mg/L except pH, temperature (°C) and fecal coliforms (colonies/100mL)

Table 6. Peat Filter No. 2 - Effluent Concentrations (mg/L).

| DATE | DAY | Type | pH | Temp(°C) | ALK. | TKN | NH4-N | NO3-N | total N | TDC | FECAL | CL- | TOTAL P | BOODS | TSS | TD6 | FSS | VSS | FD6 | VDS | | | | | |
|-----------|-----|------|-----|----------|------|-----|-------|-------|---------|-----|-------|-----|---------|-------|-----|-----|-----|-----|-----|-----|-----|---|---|-----|-----|
| 12-Jan-93 | 216 | C | 6.0 | 3.1 | 23 | 9 | 7 | 27 | 38 | 30 | | | | 4 | 0 | 353 | 0 | 0 | 231 | 123 | | | | | |
| 21-Jan-93 | 225 | C | 6.4 | 3.0 | 23 | 7 | 5 | 19 | 26 | 29 | | | 7.5 | 3 | 0 | 380 | 0 | 0 | 180 | 197 | | | | | |
| 26-Jan-93 | 232 | C | 6.8 | 3.0 | 19 | 9 | 7 | 26 | 35 | 28 | | | 7.7 | 2 | 0 | 340 | 0 | 0 | 163 | 177 | | | | | |
| 4-Feb-93 | 239 | C | 6.9 | 2.5 | | 10 | 7 | 26 | 36 | 30 | | | 7.1 | | 0 | 322 | 0 | 0 | 187 | 135 | | | | | |
| 11-Feb-93 | 246 | G | 6.4 | 2.0 | 16 | | 7 | 25 | | 30 | | | 7.1 | 3 | | | | | | | | | | | |
| 26-Feb-93 | 261 | C | 6.1 | 2.0 | 22 | 7 | 6 | 24 | 31 | 32 | | | 7.1 | | 2 | 330 | 2 | 0 | 143 | 187 | | | | | |
| 4-Mar-93 | 267 | C | | 2.0 | | 15 | 6 | 24 | 39 | 30 | | | | 3 | 0 | 349 | 0 | 0 | 177 | 172 | | | | | |
| 18-Mar-93 | 281 | C | 6.6 | 2.0 | 39 | 9 | 7 | 26 | 35 | 31 | | | | 2 | 0 | 367 | 0 | 0 | 232 | 135 | | | | | |
| 25-Mar-93 | 288 | C | 6.6 | 3.0 | 22 | 5 | 6 | 26 | 31 | 29 | | | 7.3 | 3 | | | | | | | | | | | |
| 6-Apr-93 | 302 | C | 6.2 | 4.0 | | 7 | 6 | 28 | 35 | 26 | | | 7.4 | | 0 | 353 | 0 | 0 | 195 | 158 | | | | | |
| 22-Apr-93 | 316 | C | 4.8 | 5.0 | 24 | 6 | 10 | 31 | 37 | 33 | | | 7.4 | 2 | 0 | 363 | 0 | 0 | 242 | 121 | | | | | |
| 6-May-93 | 330 | G | 5.6 | 11.0 | | 14 | 8 | 32 | 46 | | <10 | 50 | 7.1 | 2 | 0 | 366 | 0 | 0 | 173 | 193 | | | | | |
| 14-May-93 | 338 | C | | 11.0 | 24 | 9 | 7 | 35 | 44 | 44 | | | 7.2 | 3 | | | | | | | | | | | |
| 20-May-93 | 344 | C | 5.9 | 11.0 | 28 | 12 | 8 | 32 | 44 | 49 | | | 7.0 | | 0 | 419 | 0 | 0 | 145 | 274 | | | | | |
| 4-Jun-93 | 359 | C | 5.9 | | 45 | 11 | 7 | 29 | 40 | | | | 7.1 | 2 | 0 | 502 | 0 | 0 | 224 | 278 | | | | | |
| 9-Jun-93 | 364 | C | | 11.0 | | 15 | 8 | 22 | 37 | 57 | | | 7.2 | 2 | 3 | 629 | 1 | 2 | 284 | 345 | | | | | |
| 18-Jun-93 | 373 | G | 5.9 | 16.0 | | 14 | 8 | 29 | 43 | 58 | | | 6.9 | 2 | | | | | | | | | | | |
| 25-Jun-93 | 380 | G | 5.5 | 17.0 | 27 | 14 | 8 | 28 | 42 | 62 | | | 52 | 7.6 | 2 | 6 | 415 | 0 | 6 | | | | | | |
| 9-Jul-93 | 394 | G | 6.0 | 20.0 | 40 | 14 | 7 | 22 | 36 | 69 | | | 7.7 | 1 | 6 | 267 | 0 | 6 | 106 | 181 | | | | | |
| 16-Jul-93 | 401 | G | 7.0 | 21.0 | 56 | | 7 | 26 | | | | | 52 | 5.7 | 2 | 4 | 471 | 0 | 4 | 221 | 250 | | | | |
| 23-Jul-93 | 408 | C | 6.5 | 19.0 | | 11 | 5 | 20 | 31 | | | | 53 | 5.9 | 3 | 10 | 370 | 1 | 9 | 174 | 196 | | | | |
| 6-Aug-93 | 422 | C | 6.7 | 19.0 | 51 | 10 | 6 | 15 | 25 | | | | 63 | 5.8 | | | | | | | | | | | |
| 12-Aug-93 | 428 | C | 6.4 | 21.0 | 48 | 9 | 6 | 15 | 24 | | | | 66 | 6.0 | 2 | 6 | 442 | 0 | 6 | 239 | 203 | | | | |
| 26-Aug-93 | 442 | C | 6.3 | | | 13 | 6 | 13 | 26 | | | | 6.1 | 4 | 0 | 444 | 0 | 0 | 200 | 244 | | | | | |
| 4-Sep-93 | 451 | C | 6.5 | 19.0 | 59 | 11 | 5 | 15 | 26 | | | | 6.3 | 3 | | 520 | | | 218 | 302 | | | | | |
| 11-Sep-93 | 458 | C | 6.7 | 15.0 | 57 | | 4 | 16 | | | | | 61 | 11.0 | 4 | | | | | | | | | | |
| 24-Sep-93 | 471 | C | 6.9 | | 121 | 13 | 5 | | | | | | 63 | 8.4 | 6 | 5 | 472 | 0 | 5 | 229 | 243 | | | | |
| 5-Oct-93 | 482 | C | 6.8 | 13.0 | 72 | 9 | 5 | 18 | 27 | | | | 66 | 7.3 | 3 | 0 | 284 | 0 | 0 | 238 | 46 | | | | |
| 15-Oct-93 | 492 | C | 6.7 | 13.0 | 53 | 9 | 5 | 20 | 29 | | | | 66 | | | 0 | 364 | 0 | 0 | 198 | 166 | | | | |
| 26-Oct-93 | 503 | C | 6.7 | 9.0 | 40 | 8 | 4 | 24 | 32 | | <2 | 58 | 7.2 | 1 | 0 | 320 | 0 | 0 | 201 | 119 | | | | | |
| 5-Nov-93 | 513 | C | 6.6 | 7.0 | | 5 | 4 | 27 | 32 | | | | 49 | 7.5 | 1 | 380 | 0 | 1 | 199 | 181 | | | | | |
| 13-Nov-93 | 521 | C | 6.5 | 6.0 | 27 | 7 | 4 | 26 | 33 | | | | 53 | 7.4 | 1 | 11 | 365 | 7 | 4 | 262 | 103 | | | | |
| 30-Nov-93 | 538 | C | 6.4 | 7.0 | 23 | 7 | 4 | 30 | 37 | | | | 56 | | 3 | | | | | | | | | | |
| 11-Dec-93 | 549 | C | 6.3 | 3.5 | 18 | 6 | 4 | 30 | 36 | | | | | | | 3 | 384 | 0 | 3 | 210 | 174 | | | | |
| 22-Dec-93 | 580 | C | 6.2 | 6.0 | 19 | 7 | 6 | 34 | 41 | | | | | | | | | | | | | | | | |
| AVG | | | | | | | | | | | | | | | | | | | | | 392 | 0 | 2 | 203 | 189 |
| ST. DEV | | | | | | | | | | | | | | | | | | | | | 78 | 1 | 3 | 38 | 67 |

Note: all units as mg/L except pH, temperature (°C) and fecal coliforms (colony/100mL)

Note: all units as mg/L except pH, temperature (°C) and fecal coliforms (colonies/100ml.)

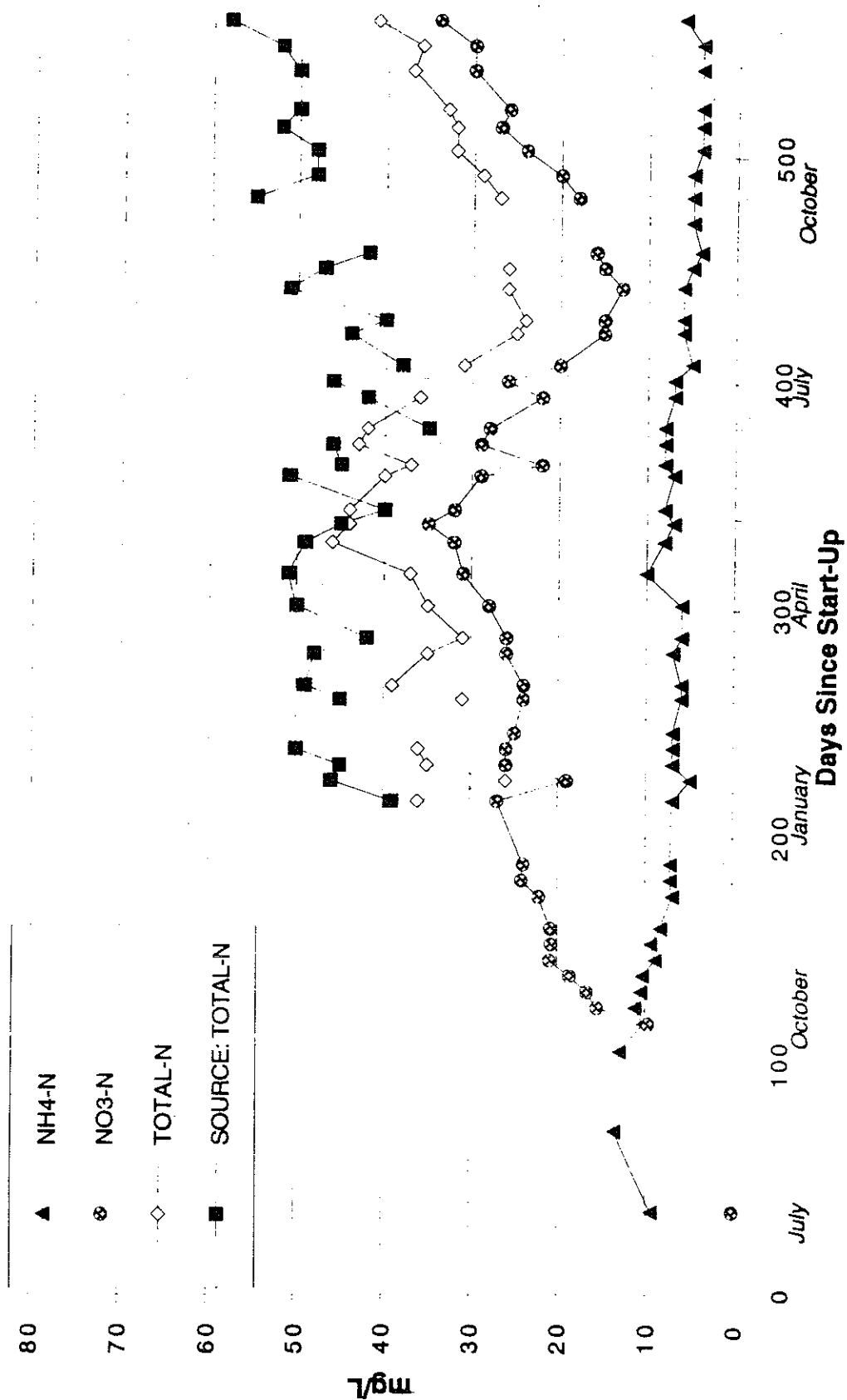


Figure 4. Peat Filter No. 2 Nitrogen

been reported (Nichols and Boelter, 1982; Lance and Whisler, 1972). Sorption of ammonia and organic nitrogen followed by later release may explain this result. It should also be noted that this filter was started up later than peat filter No. 2 and during cooler weather. Furthermore, seeding of nitrifiers, which preceded start-up of the sand filter systems and peat filter No. 2, was not practiced for this unit. Clearly, the shallower filter with a limited anoxic zone did not produce the desired nitrogen removal.

DISCUSSION

Results of the experimental on-site field studies at BRFC are preliminary even though the units have been in service for about 18 months. Several changes in design have taken place during that time in an effort to enhance performance. The sand filter-anaerobic upflow system appears to be an excellent candidate for nitrogen removal to date. Even in the coldest months when wastewater temperatures were close to zero, nitrification/denitrification processes continued to function effectively. Further modifications of these flow regimes are underway to ascertain the lowest cost but highest reliability system.

The peat filters produced high quality effluent but nitrogen removal was marginal. Further evaluation of this concept will continue another year.

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