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Jerry T. Elliott

Daniel S. Filip

James H. Reynolds

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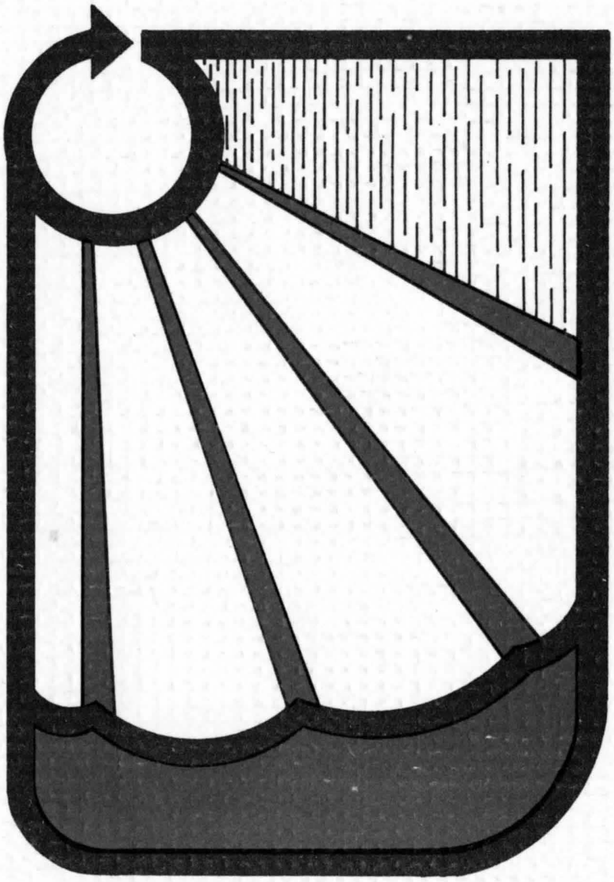

PRJER033-1

Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, Utah 84322

June 1976

DISPOSAL ALTERNATIVES FOR INTERMITTENT SAND FILTER SCRAPINGS UTILIZATION AND SAND RECOVERY

by

Jerry T. Elliott, Daniel S. Filip, and
James H. Reynolds

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ABSTRACT

A three phase study is used to develop disposal alternatives and cost analysis for algae laden sand scrapings removed from intermittent sand filters used to polish wastewater lagoon effluent. Phase I, Irrigation Technique, explores the feasibility of supplying sufficient water to sand scrapings to leach out entrapped material. Details of removal with amount of water applied are presented.

Phase II, Soil Application, tests with lysimeters soil response to application of the algae laden sand material. Physical and chemical parameters are not markedly altered where algae laden sand is applied to the soil surface.

Phase III, Plant Bioassays, grew tall fescue on lysimeters which had algae laden sand scrapings applied and compared this growth response with lysimeters having no additives to a clay soil and lysimeters having ammonium nitrate added as fertilizer.

Results indicate that all three disposal alternatives are viable recourses for sewage sand filter sand deposition and utilization. Cost analyses indicate that an irrigation technique may be less expensive.

Key Words: Intermittent sand filtration, lagoons, waste stabilization ponds, algae, irrigation, soil conditioner, land application

ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

Nature of the Problem

Wastewater stabilization lagoons provide economical wastewater treatment for over 4,000 communities in the United States. However, with the adoption of the 1972 Water Quality Amendment Acts (PL 92-500), effluent discharge standards were established which most lagoons are unable to meet. Thus, lagoon effluent must be "polished" or upgraded before being discharged to a receiving stream.

One of the viable alternatives for polishing lagoon effluents is intermittent sand filtration. Intermittent sand filtration provides a means of reducing suspended solids (algae) and removing the effluent biochemical oxygen demand (BOD_5). The operation of the intermittent sand filter involves intermittently applying lagoon effluent to a sand filter bed. As the wastewater percolates through the sand filter bed, the lagoon effluent suspended solids and BOD_5 are removed.

The removal process causes a "schmutzdecke" or organic mat to form on the filter bed surface. In addition, trapped suspended solids (mainly aglae) fill in the sand pores in the top 2.5 to 5 centimeters (1 to 2 inches) of the filter bed. Thus, the filters become plugged and the top 2 to 5 centimeters (1 to 2 inches) of the sand filter bed must be removed.

The "scraping" of the plugged filter bed to remove the top 2 to 5 centimeters (1 to 2 inches) of spent filter sand and the washing or rejuvenation of this sand for reuse on the filter is the major operational cost associated with the intermittent sand filtration of lagoon effluents. In general, communities which utilize a lagoon-intermittent sand filtration system for wastewater treatment do not have sufficient resources available to support large operation and maintenance expenditures. Thus, an economical method for rejuvenation of spent intermittent sand filter sand needs to be developed.

This report presents the findings of a one year study that evaluated two low cost alternatives for rejuvenation and disposal of spent intermittent sand filter sand and determined the pollution potential of the spent sand filter material. The first phase was designed to determine the feasibility of a low cost irrigation technique for spent filter sand rejuventation and subsequent reuse. This phase also delineated the possible environmental hazard these spent filter scrapings may have. Phase two of the study was designed to evaluate the feasibility of using the spent filter sand as a soil conditioner. A third phase investigated plant growth response in a mixture of spent filter scrapings and soil.

Objectives

General

The general objective of this study was to evaluate the feasibility of two low cost alternatives for rejuvenation–reuse or disposal of spent intermittent sand filter sand.

Specific

To satisfy the above general objective, the following specific objectives were undertaken:

1. Determine the performance of an irrigation technique for rejuvenation of spent filter sand.

2. Determine the quality of effluent or leachate generated by the irrigation technique.

3. Evaluate alternative methods for disposal of the irrigation technique effluent or leachate.

4. Develop design criteria for the irrigation technique.

5. Develop the costs associated with the irrigation technique.

6. Determine the effect on soil properties of applying spent intermittent sand filter sand on various types of soil.

7. Determine the effect on the soil-water solution by applying spent intermittent sand filter sand on various types of soil.

8. Determine the effect on plant productivity when spent intermittent sand filter sand is used as a soil conditioner.

9. Determine the costs associated with employing spent intermittent sand filter sand as a soil conditioner.

Scope

The study was conducted over a twelve month period with laboratory and pilot scale facilities. The costs were developed for a full scale system and were based on the laboratory and pilot plant data. This is only a preliminary study and additional research on a large scale is necessary to validate these results and to develop exact full scale system response and cost information. However, the results of this study clearly indicate the feasibility and practicality of the systems studied.

CHAPTER II

LITERATURE REVIEW

Intermittent Sand Filters

Efficiency of intermittent sand filters

The history of intermittent sand filters as a means of water and wastewater treatment is well outlined by Marshall (1973), Reynolds et al. (1974) and Hill (1976). Many authors including Grantham, Emerson, and Henry (1949); Calaway, Carroll, and Long (1952); Calaway (1957); Marshall (1973), and Marshall and Middlebrooks (1974) have described plugging and the necessity for periodic filter cleaning. However, none of these authors mention that such algae encrusted sand can act as a pollution source. This spent filter sand is capable of exerting a significant biochemical oxygen demand (BOD_5) and raising nutrient levels of groundwater and receiving streams if allowed to leach indiscriminately through a porous soil or if discharged untreated.

Marshall and Middlebrooks (1974) reported that suspended solids removal varied from 83 percent to 43 percent from a 0.17 mm effective size sand. Grantham, Emerson and Henry (1949) tabulate suspended solids removal between 89 and 96.5 percent for a 0.25 mm sand size on a 76.2 cm (30 in.) sand bed. Harris et al. (1975) found that filter effluent exceeded 5 mg/l suspended solids only 15 percent of the time in a one year study.

Harris et al. (1975) also demonstrated that intermittent sand filters were able to maintain a BOD below 5 mg/l 93 percent of the time when the filter is maintained as an aerobic system. BOD removals from 81 to 93 percent were observed by Marshall and Middlebrooks (1974) for 0.25, 0.30 and 0.45 mm effective size sand. Somewhat higher removal from a 76.2 cm (30 in.) bed 93.5 percent to 98.5 percent was observed by Grantham, Emerson and Henry (1949) at the University of Florida on a 0.25 mm sand size. Shallower beds, 45.72 cm (18 in.) removed only slightly less efficiently. Removal was 73.9 to 98.4 percent.

Series intermittent sand filtration has been shown to be an effective means of increasing filter effluent quality. Hill (1976) reported filter effluents with BOD_5 and suspended solids concentrations consistently below 20 mg/l while employing a pilot scale three stage series intermittent sand filter.

Nature of intermittent sand filters

Because intermediate sand filters produce an oxidized effluent, the filters employ a combination of physical and biological processes. Calaway, Carroll and Long (1952) took samples of the filter surface and found an extremely variable heterotropic bacterial population. As loading increased, this bacterial population also increased. *Flavobacterium, Bacillus, Alcaligenes, Streptomyces* and *Nocardia* genera were found to predominate the population on the sand filter surface. Calaway (1957) and Calaway, Carroll, and Long (1952) found that this bacterial population was predominately located on the filter surface. Organisms below approximately 30 cm (12 in.) of sand did not receive sufficient food to maintain life. These authors have also found that coliforms were removed throughout the entire filter depth. Coliforms were, however, primarily removed by the filter surface.

Filter cleaning

A number of cleaning methods have been devised for the rejuvenation of clogged intermittent sand filters. Story (1909) found that disturbing the algae mat by raking followed by drying was an acceptable means of rejuvenating a plugged filter used for pretreatment of a culinary water supply. Because he noted that such a cleaning method also caused increased penetration of particles, he "was always careful not to use this method too frequently." Saville (1924) determined that five men could rake a 0.203 ha (1/2 acre) sand filter bed in two hours and that such rakings provided adequate cleaning about one fourth of the time.

The other method of cleaning noted by Story (1909) was scraping. Story used a hoe to scrape the filter. The hoe allowed the removal of a thin coat of sand and the material was windrowed and collected in wheelbarrows. From here the sand was dumped into a reservoir. Saville (1924) also discusses scraping of intermittent sand filters. Eleven men were used for two shifts to scrape the same bed it took five men two hours to rake.

Streander (1940a) discussed the application of sand filtration to sewage. An important requisite to good filter operation was maintenance of a clean filter. Streander (1940a) also discussed the various methods of cleaning sand filters. These methods were all mechanical and installed on the filter surface. He mentioned that filter wash water did not need to be refiltered after washing because the suspended matter settled quite well. Streander (1940b) discusses in detail two mechanical sand surface cleaners. Daniels (1945) also mentions the importance of a clean filter surface. He mentions that accumulated materials must be scraped and removed as soon as interference is noted. When cleaning is performed anything is acceptable even plowing or harrowing.

Metcalf and Eddy (1935) however, caution against the plowing and harrowing of intermittent sand filters because the mixing of deposited fine materials will become mixed with the sand and decrease filter capacity. Raking was shown to be less than half as effective at rejuvenation of intermittent sand filters used for wastewater lagoon effluent filtration (Reynolds et al., 1975).

Babbitt and Baumann (1958) also mention clogging. The clogging mat is composed of "hair, paper and other tenacious materials." They stress that as long as the filter is draining properly, the mat should be left undisturbed. When the filter does become clogged 1.91 to 5.08 cm (3/4 to 2 in.) are removed.

Gaub (1915) and Karalekas (1952) have reported on the use of hydraulic ejectors for cleaning intermittent sand filters. These mechanical cleaners involve water under pressure from below while scrapings were shoveled onto the water. The resulting suspension was transported to further water washing, storage bins or other filters.

Gaub (1915) presents a summary of cleaning methods both hand and mechanical. The Brooklyn method involves a rapid stream of water being passed over the bed while men work the surface sand. Gaub (1915) also discusses some filter cleaning machines. The Blaisdell machine uses a crane to place hollow teeth over the filter surface. Water forced down through the teeth scours the sand. A suction pump removes the dirt that is stirred up. The wash water is passed to a gutter. Where the collected water in this gutter is sent was not mentioned. A second machine, the Michols washer, uses a large cylinder to clean the dirty sand on the filter bed without loss of much sand. Baffles are sometimes added to increase wash time in the cylinder.

Although all of the above authors mention the removal of sand from the filters, Story (1909) mentions the ultimate sink of the encrusted sand. He reported that sand was "wasted over the bank into the reservoir."

Sand Filter Scrapings as a Soil Amendment

Another possible use of spent intermittent sand filter sand is as a soil amendment. Many authors, Day, Tucker, and Vavich (1962), Sopper and Kardos (1973), McCalla (1974), Larson (1974), and others show that secondary sewage effluent can be used on croplands and forest for effluent polish, does not destroy soil characteristics, and provides nutrients essential to crops. Nizova (1970) showed that beneficial effects of clay addition to sandy soil can be achieved. Addition of sand to clay soils can also possibly increase production of these soils. Hidding and Wind (1963), in the Netherlands, and Bakker (1964), in Germany, investigated the effect of sand as a clay soil amendment. The high cost of sand may be a reason why few American researchers have pursued this topic.

Because heavy metals are absorbed by both algae and silica (Filip and Lynn, 1972; Glooschenko, 1969), heavy metal magnification may occur through plants grown in spent filter sand. Larson, Gilley, and Linden (1975) state that concern for heavy metals is the factor that limits the amount of sewage sludge applied to the land. It may also limit sand scraping application.

CHAPTER III

PROCEDURES

Phases of Study

The study was divided into three phases. Phase I: "Sand Rejuvenation" was designed to evaluate the feasibility of a new irrigation technique for the rejuvenation or washing of spent intermittent sand filter sand prior to subsequent reuse on the intermittent sand filter. Phase II: "Soil Conditioner" was designed to evaluate the possibility of utilizing the spent intermittent sand filter sand as a soil conditioner on different soil types. Phase III: "Plant Bioassay" was designed to determine the fertilizer value of the spent filter sand which had been mixed as a soil amendment with a relatively non-productive soil. The plant bioassay was intended to determine the affect of the spent filter sand on plant productivity.

Phase I: Sand Rejuvenation

Irrigation technique

The irrigation technique for rejuvenation or washing of spent filter sand involves the placing of the spent filter sand on a conventional sludge drying bed or a suitable impervious surface so that effluent or leachate from the process may be collected. The spent sand is then irrigated by a conventional spray irrigation system with clean irrigation water at a given application rate until the spent sand is rejuvenated and ready for reapplication to the intermittent sand filter bed. The effluent or leachate from the system is collected and either recycled to the lagoon system, utilized as a nutrient rich irrigation water or discharged to a receiving stream.

Spent filter sand

Six prototype intermittent filters, 7.62 m x 10.97 m (25 ft x 36 ft), were constructed in early 1974 near the Logan, Utah, Municipal Sewage Lagoons under EPA Contract No. 68-03-0281. The effective sand size is 0.17 mm with a uniformity coefficient of 9.74. Sand depth is 0.914 m (3 ft) below which lies 0.305 m (1 ft) of graded gravel (Reynolds et al., 1974).

Hydraulic loading rates have been 306, 613, 919, 1,225, 1,523, and 1,838 m^3/ha/day (0.2, 0.4, 0.6, 0.8, 1.0, and 1.2 mgad). When these filters plugged, the spent filter sand was collected and used for all phases of the study.

Pilot plant

To investigate the rate of sand rejuvenation by the irrigation technique, six sand basins were constructed at the Utah Water Research Laboratory, two each 15.2 cm, 30.5 cm, and 61 cm deep (6, 12, and 24 in.). Each sand basin was divided to yield 12 separate areas 120 cm by 120 cm (47.5 in. by 47.5 in.). Unused sand was applied to one side of each basin to a depth of 12, 21, and 46 cm (4.7, 8.3 and 18.1 in.), respectively. Care was taken to obtain the unused sand from the same place as the filter sand was originally acquired. Sand scrapings were applied to the other side of the basin to the same depth. These six basins were placed on the roof of the Utah Water Research Laboratory. Three were spray irrigated with 5 cm, about 71 liters (1.97 in. or approximately 18.8 gallons) of tap water per weekday and three were left unirrigated to investigate the effects of natural environmental conditions and natural precipitation on the scrapings. All were exposed to natural summertime northern Utah climate. Sand was scattered on the roof to minimize the effects of the black tar roof absorbing excessive heat.

Each of the six basins was fitted with three 1 cm (0.4 in.) drain holes and was set at a slope of 4 percent to facilitate drainage. The effluent from each of the boxes was collected by rubber hose 1.25 cm diameter (0.5 in.) and deposited in separate covered 66 liter (17.4 gallon) polyethylene containers.

Effluent was sampled two hours after application of irrigation water. Water available for collection varied from 20 liters to 60 liters (5.3 to 15.9 gallons) depending on efficiency of the drainage system in that basin and upon the depth of sand in the basin. Sample water was thoroughly mixed with a small cellulose acetate pipe and then collected in 4 liter plastic containers. Twice a week the effluent from the irrigated basins was analyzed. When effluent concentrations had decreased effluent was sampled once a week.

The leachate was analyzed for ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), orthophosphorus, biochemical oxygen demand (BOD_5), total suspended solids (TSS), volatile suspended solids (VSS), sodium, hardness, and electroconductivity. Analysis of these parameters indicated how high the pollution potential of the material was as well as how fast the biological components were decomposed. Sodium, hardness, and electroconductivity measurements were conducted to calculate the sodium adsorption ratio (SAR).

Background nutrient levels were found by analyzing leachate from the unused sand section of each basin.

On sample days a 1.9 cm (0.75 in.) cellulose acetate pipe was inserted in randomly determined sites in the basins. A small 1.5 cm (0.59 in.) shovel was then used to obtain a core sample of the sand. This core sample was dried and placed in a muffle furnace at 550°C for two hours to obtain measurements of volatile solids in the sand media (see Table 1).

This experiment was terminated when the BOD, VSS, and NO_3 concentrations were well within and appeared to remain within the standards for Class C receiving waters as defined by the State of Utah (1974). Such concentration should indicate that algae decomposition had reached very low levels and that the sand should be cleaned sufficiently to be reusable.

To determine if natural precipitation could rejuvenate the spent filter sand, the non-irrigated basins were not disturbed from July 25, 1975, to April 8, 1976. They were exposed to natural light and weather conditions for 258 days. Rainfall in the area is between 38 and 43 cm (15 and 17 in.) per year. On April 8, 1976, 71 liters (18.8 gallons) of water was applied to the basins and the effluent was collected and analyzed for biochemical oxygen demand, total suspended solids, volatile suspended solids, total phosphorus, orthophosphorus, ammonia, nitrate, and nitrite.

Phase II: Soil Conditioner

Lysimeters

Lysimeters were employed to determine changes in nutrient release and permeability when spent filter sand was applied to four different soil types. The four locally available soils are described in Table 2 and are representative of soils found in the western-central intermountain area of the United States. The lysimeters were 53 cm deep and 53 cm square (20.9 in.). Effluent tubes were located at the 8.9 cm (3.5 in.) depth, at the 39.5 cm (15.5 in.) depth and on the bottom. The lysimeters were filled with soil to within 55 cm (1.97 in.) of the surface. The bottom provided a two way slope that provides complete drainage. Drains were provided with a 5 percent slope. The units were built with 1.59 cm (5/8 in.) exterior plywood and water proofed with marine glass resin. Drains were 7.62 cm (3 in.) Polyvinylchloride (PVC) with the top half removed to within 7.6 cm (3 in.) of the sidewall. This feature prevented the interception of unfiltered water samples traveling down the sidewall. Stainless steel wire mesh was placed over all drain outlets to prevent clogging. Washed pea gravel was placed 3.5 cm (1.4 in.) deep in the bottom of the lysimeter and in the mid-drains at the 8.9 cm (3.5 in.) and 39.4 cm (15.5 in.) depths.

Analysis

Soils (Table 2) were collected on site by shovels and transported to the Utah Water Research Laboratory. The lysimeters were loaded in 10 cm (4 in.) levels and each level was packed and wetted to attain maximum and uniform compaction among all the lysimeters.

Table 1. Procedures for analyses performed.

Volatile Suspended Solids	Standard Methods	APHA, AWWA, WPCF, 1971
Total Phosphorus	EPA Methods	EPA, 1974
Orthophosphorus	Strickland & Parsons (Murphy-Riley Technique)	Strickland & Parsons, 1968
Ammonia	Solorzano (Indophenol)	Solorzano, 1969
Nitrite	Strickland & Parsons (Diasotization Method)	Strickland & Parsons, 1968
Nitrate	Strickland & Parsons (Cadmium-Reduction Method)	Strickland & Parsons, 1968
Sodium	Standard Methods (Flame Photometric Method)	APHA, AWWA, WPCF, 1971
Hardness	Standard Methods (EDTA Titrimetric Method)	APHA, AWWA, WPCF, 1971
Conductivity	Standard Methods	APHA, AWWA, WPCF, 1971
Heavy Metals (Cu, Zn, Hg, Cd, Pb, Fe)	Atomic Absorption Spectrophotometry	EPA, 1974

Table 2. Description, location, and use of the four Utah Great Basin soils studied.

Soil	Texture	Sample Site Location	Use
Nibley [a]	Silty Clay Loam	Field N. of shed at USU South Farm	Irrigated crops and natural pasture
Parleys [a]	Silty Loam	2.4 km E. of Hyde Park on alluvial fan	Irrigated grain crops and natural pasture
Draper [b]	Sandy Loam	1 km S. and 1.7 km W. of Perry on alluvial fan	Irrigated fruit crops and natural pasture
USU Reclamation Farm	Clay	4 km W. and 1.6 km N. Logan	Irrigated grain crops and natural pasture

[a] Erickson, A. J. and V. L. Mortensen. 1974. Soil Survey of Cache Valley Area, Utah Parts of Cache and Box Elder Counties. Soil Conservation Service, USDA. Washington, D.C.

[b] Chadwick, R. S. et al. 1975. Soil Survey of Box Elder County, Utah, Eastern Part. Soil Conservation Service, USDA. Washington, D.C.

Prior to application of spent filter sand scrapings a soil sample was sent to the USU Soil Plant and Water Analysis Laboratory to measure pH, salinity as electroconductivity, phosphorus, potassium, texture percent organic carbon, cation exchange capacity, percent saturation, water soluble sodium, exchangeable sodium and amount of lime.

For three weeks before the scrapings were applied water was added to the lysimeters to establish saturated soil conditions.

Eight lysimeters were filled with the four soil types (two per soil type). Four soils were not exposed to sand scrapings and were therefore maintained as a control (Figure 1). A well mixed sample of spent filter sand from the prototype intermittent sand filters was spread to a uniform depth of 3 cm (1.18 in.) on each soil type in each of the four lysimeters. The scrapings were placed on the top of the soil. The soils were irrigated for six weeks.

Twice a week all the lysimeters were exposed to simulated rainfall or irrigation totaling 2.5 cm (1 in.). "General Electric cool light" fluorescent light bulbs were maintained above all the lysimeters on a 12 hours on, 12 hours off schedule to provide a diurnal fluctuation of light. The temperature was maintained

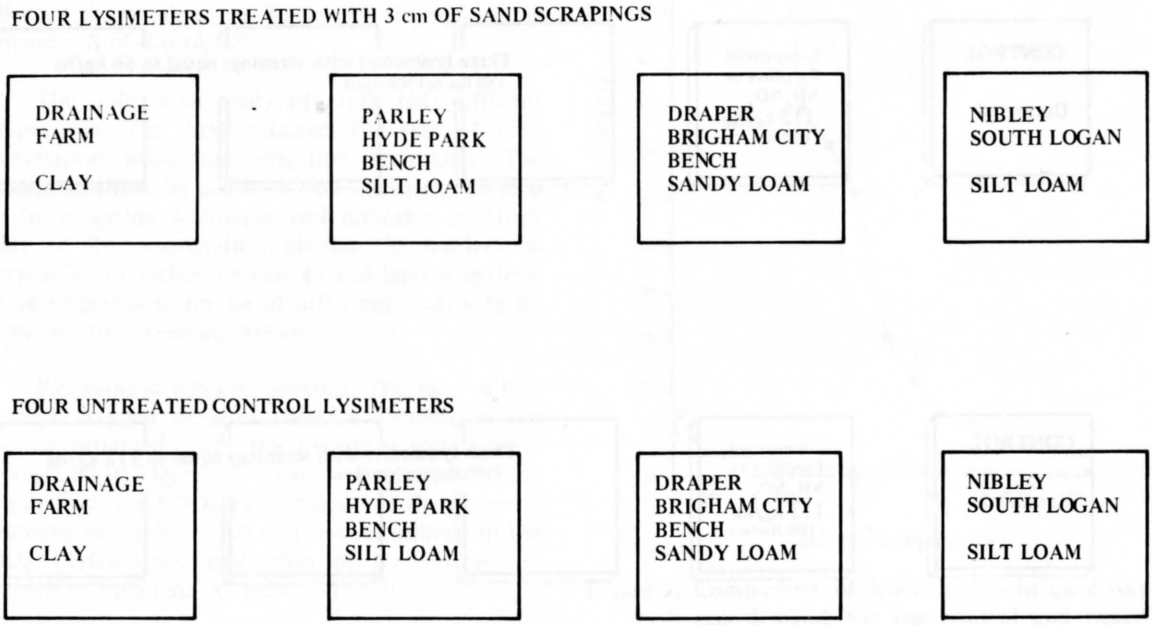

Figure 1. Experimental design to determine the affect of spent filter sand on various soil types (Phase II: Soil Conditioner).

within 3 degrees of 20°C (68°F). Weekly effluent from the soils was analyzed for volume, ammonia, nitrite, nitrate, orthophosphorus, and total phosphorus. All analyses were performed according to the procedures outlined in Table 1.

Phase III: Vascular Plant Bioassays

Design

The vascular plant bioassay tested the effects of different doses of spent filter algae-sand scrapings on a grass type commonly grown in northern Utah pastures. A clay soil was selected because it was felt a clay soil would be most assisted by the addition of the sand. Lysimeters of identical design as Phase II were used. A sample of well mixed algae-sand scrapings was analyzed for total nitrogen. On the basis of these data three lysimeters each received application rates of 56 kg/ha and 112 kg/ha (50 and 100 lb/ac). A 112 kg/ha dose of ammonium nitrate commercial fertilizer was applied to the soil on two lysimeters. Two lysimeters were left unfertilized as controls (Figure 2).

All of the lysimeters were seeded with tall fescue (Figure 2). Lighting was maintained uniformly with a 12 hour off and 12 hour on schedule and water was applied to all lysimeters when drying began to appear on the clay surface of any one lysimeter. Due to the nature of clay soils this prevented water from becoming a limiting factor.

Analysis

Germination and growth rates of the grass were monitored. Once the grass was established (five weeks after germination) clippings were made on the entire lysimeter two weeks apart from the same elevation on all lysimeters. Production of the grass on the different lysimeters was compared with the various application rates and was evaluated by comparing dry weight produced. Dry weight was determined by drying the grass at 103°C for 24 hours. Placing the samples in burned crucibles and placing this into a muffled furnace at 555°C for two hours determined ash weight. Notes were kept on the health and appearance of the grass and any physiological changes resulting from the treatments were noted.

Cost Analysis

Cost analysis for design of disposal methods of plugged sand filter sand were performed by analyzing what method of application, treatment or removal would be used for a large scale filter system. Local contractors and retailers provided information as to cost of equipment for aspects of disposal.

Statistical Analysis

A Hewlett-Packard 25 Programmable calculator was used for statistical analysis of means, variance, regression and t tests. These analyses were performed as in Mendenhall (1971) and Middlebrooks (1976).

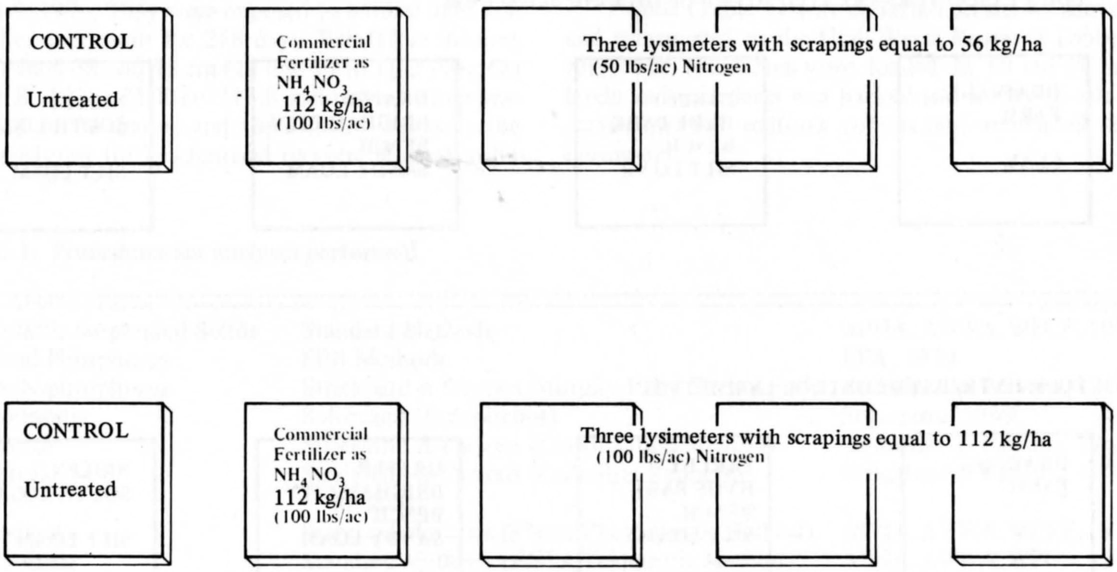

Figure 2. Experimental design of vascular plant bioassay to determine the effect of different algae-sand scraping dosages and recommended dosage of fertilizer.

CHAPTER IV

RESULTS AND DISCUSSION

Phase I: Sand Rejuvenation

Phase I: "Sand Rejuvenation" was designed to determine the feasibility of rejuvenating spent filter sand by a new irrigation technique and to determine if spent filter sand could be rejuvenated by exposure to natural weather conditions without supplimental additions of water. This results and discussion section is divided into two parts. Part A: "Irrigation," will discuss the feasibility of the irrigation technique. Part B: "Natural Exposure," will discuss the results of exposure of spent filter sand to natural weather conditions.

Part A: Sand rejuvenation by irrigation

Irrigation of the experimental basins began on July 25, 1975, with the initial effluent or leachate analysis being performed on that date. Sampling and analysis continued on a routine basis until October 10, 1975, when the concentration of significant parameters in the basin effluent or leachate had reached acceptable levels. The data included in this section are a summation of this two and one half month period. A complete listing of all the data collected is contained in Tables 14 through 30 in Appendix A of this report.

The data were analyzed from two different perspectives. The first indicates the rate of sand rejuvenation using the irrigation technique. The second identifies the quality of the leachate generated by the irrigation technique and indicates at which point of the rejuvenation process the leachate is acceptable for either recycle to the lagoon system, use as irrigation water, or of sufficient quality to be discharged to a receiving stream.

Biochemical oxygen demand. The rate of biochemical oxygen demand (BOD_5) decrease in the leachate obtained from the irrigation technique is summarized in Figures 3, 4 and 5. A summary of the data analysis for BOD_5 performance of the system is presented in Table 3. All of the data utilized in the BOD_5 performance evaluation of the system are reported in Appendix A, Tables 14 to 30.

The BOD_5 concentration of the experimental basins leachate will be compared to (i) that of the control basin, (ii) the 30.0 mg/l standard established by PL 92-500 and (iii) the 5.0 mg/l standard proposed for Class C waters by the State of Utah (1974).

The leachate BOD_5 concentrations of the control basins were less than 5.0 mg/l except on one occasion which occurred near the beginning of the study. The increase in control leachate BOD_5 during the second analysis is probably due to either experimental error or to some type of flushing action occurring within the basin. In general, control leachate BOD_5 levels were consistently below 1.0 mg/l after 100 cm (39.4 in.) of water had been applied to the basins.

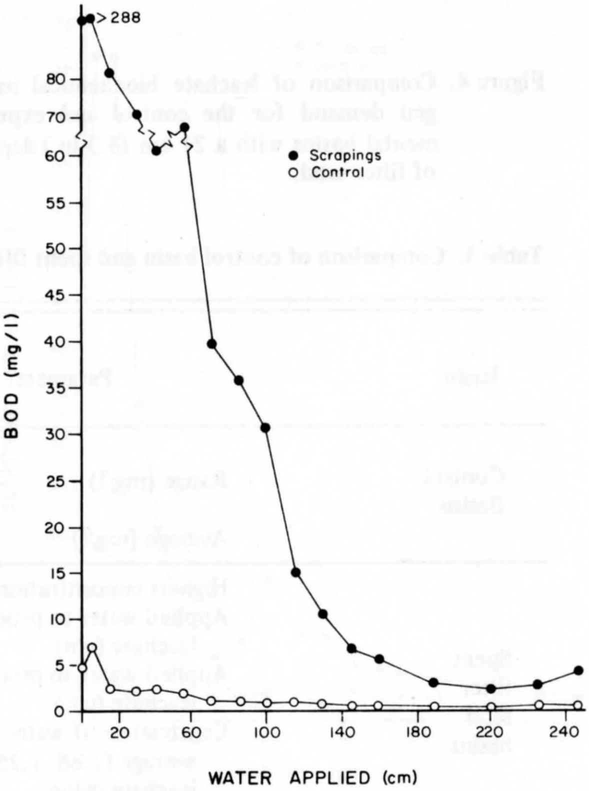

Figure 3. Comparison of leachate biochemical oxygen demand for the control and experimental basins with a 46 cm (18.1 in.) depth of filter sand.

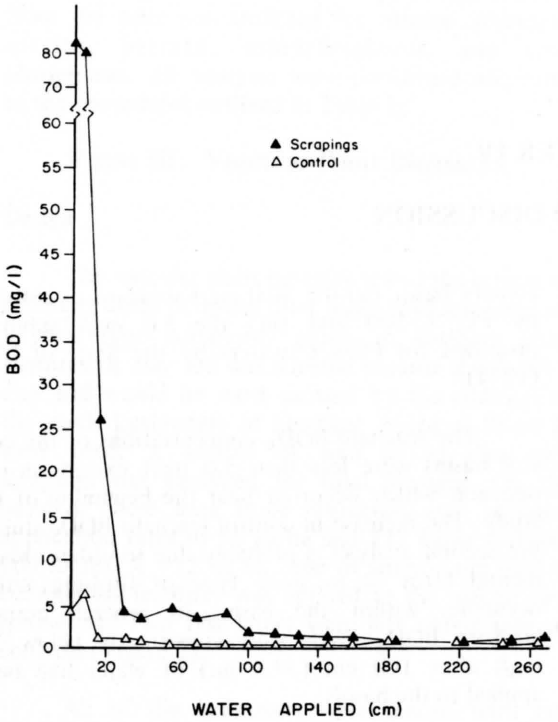

Figure 4. Comparison of leachate biochemical oxygen demand for the control and experimental basins with a 21 cm (8.3 in.) depth of filter sand.

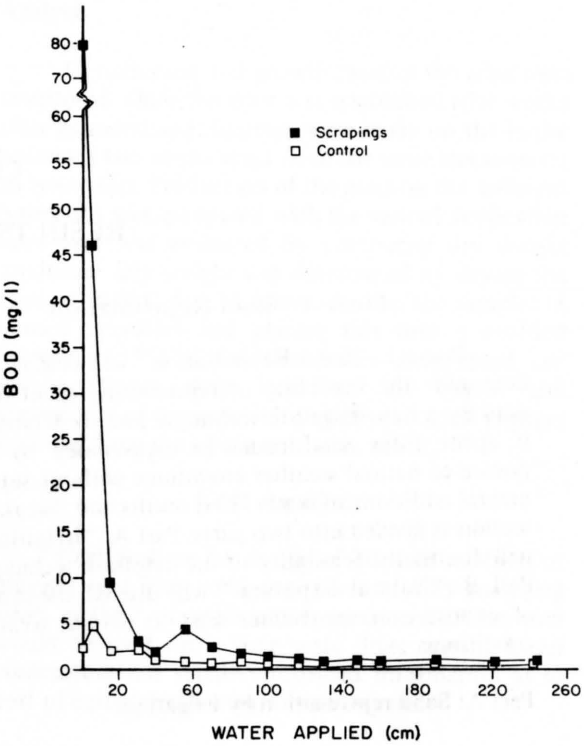

Figure 5. Comparison of leachate biochemical oxygen demand for the control and experimental basins with a 12 cm (4.7 in.) depth of filter sand.

Table 3. Comparison of control basin and spent filter sand basin biochemical oxygen demand performance.

Basin	Parameter	Depth of Sand (cm)		
		46	21	12
Control Basins	Range (mg/l)	0 to >6.8	0.2 to 6.4	0.3 to 4.9
	Average (mg/l)	1.88	1.25	1.20
Spent filter sand basins	Highest concentration (mg/l)	>288	93.4	79.2
	Applied water to produce 30 mg/l leachate (cm)	115	15	15
	Applied water to produce 5 mg/l leachate (cm)	160	55	30
	Centimeters of water applied to produce average (1.88, 1.25, 1.20 mg/l) control leachate value	>270[a]	145	100
	Ratio of liters of applied water: liter of sand needed to produce 5 mg/l BOD	4.1	2.6	2.5

[a] Leachate did not reach stated value.

The initial leachate BOD$_5$ concentrations from the basins containing spent filter sand at depths of 46 cm, 21 cm, and 12 cm (18.1, 8.3 and 4.7 in.) was 270 mg/l, 93 mg/l and 79 mg/l respectively. The rate of BOD$_5$ decrease for each of the experimental basins appears to be related to the depth of spent filter sand being treated (Figure 2, 3 and 4). As reported in Table 3, the 46 cm (18.1 in.) depth of spent filter sand required 115 cm (45.3 in.) of applied water to produce a leachate BOD$_5$ concentration of less than 30 mg/l. While the 21 cm (8.3 in.) and 12 cm (4.7 in.) depth of spent filter sand required only 15 cm (5.9 in.) of applied water to reach the same level.

A similar pattern results in attempting to produce a leachate with a BOD$_5$ concentration of 5.0 mg/l. The 46 cm, 21 cm, and 12 cm (18.1, 8.3, and 4.7 in.) depth of spent filter sand required 30 cm (11.8 in.), 55 cm (21.7 in.), and 160 cm (63.0 in.) of applied water respectively to produce leachate BOD concentrations less than 5.0 mg/l. The 46 cm (18.1 in.) depth of spent filter sand did not produce a leachate BOD$_5$ concentration equivalent to the control basin even after 270 cm (105 in.) of water had been applied. However, the 21 cm (8.3 in.) and 12 cm (4.7 in.) depth of spent filter sand produced leachate BOD$_5$ concentration equal to or less than the control basin after 145 cm (57.1 in.) and 100 cm (39.4 in.) of applied water respectively.

The ratio volume of applied water to volume of spent sand treated to produce a leachate BOD of 5 mg/l for the 12 cm, 21 cm, and 46 cm depth of spent filter sand was 2.5, 2.6 and 4.1 respectively. This suggests that the shallower depths of spent filter sand require less applied water to rejuvenate a given volume of sand.

A spent filter sand depth of 21 cm (8.7 in.) will produce an acceptable leachate for discharge after application of 55 cm (21.7 in.) of irrigation water. In addition, the ratio of volume of applied water to volume of sand treated appears to favor the use of a 21 cm (8.3 in.) depth of spent filter sand in the irrigation technique rejuvenation process. Although the ratio for the 21 cm (8.3 in.) depth is slightly higher than that for the 12 cm (4.7 in.) depth (i.e., 2.6 compared to 2.5) the ability to handle a greater volume of spent sand in a given area would favor the use of 21 cm (8.3 in.) depth.

Suspended solids. The total suspended solids concentration of the experimental basin leachate was compared to (i) that of the control basins, (ii) the 30.0 mg/l standard established by PL 92-500 and (iii) the 5.0 mg/l standard proposed for Class C waters by the State of Utah (1974).

A comparison of the leachate suspended solids concentrations for the control and experimental basins with equivalent depths of filter sand are shown in Figures 6, 7, and 8. A complete listing of the data is reported in Appendix A, Tables 14 to 30.

The initial leachate suspended solids concentrations for the control basins with 46 cm, 21 cm, and 12 cm (18.1, 8.3, and 4.7 in.) depths of sand were 1.4 mg/l, 11.4 mg/l and 12.0 mg/l respectively. The decrease in control leachate suspended solids concentration is probably due to a self filtering action by the filter sand.

The high suspended solids concentration of 27.6 mg/l in the control basin with a 21 cm (8.3 in.) depth of sand indicates "washing out" of fine inorganic material. This phenomenon has been reported when water was first applied to intermittent sand filters (Harris et al., 1975). The 117 mg/l leachate suspended solids concentration from the control basin with 12 cm (4.7 in.) of sand when 30 cm (11.8 in.) of water had been applied is a result of disruption of the sand in the basin when a sand core sample was taken.

Leachate suspended solids concentrations in the spent filter sand basins were somewhat variable. In

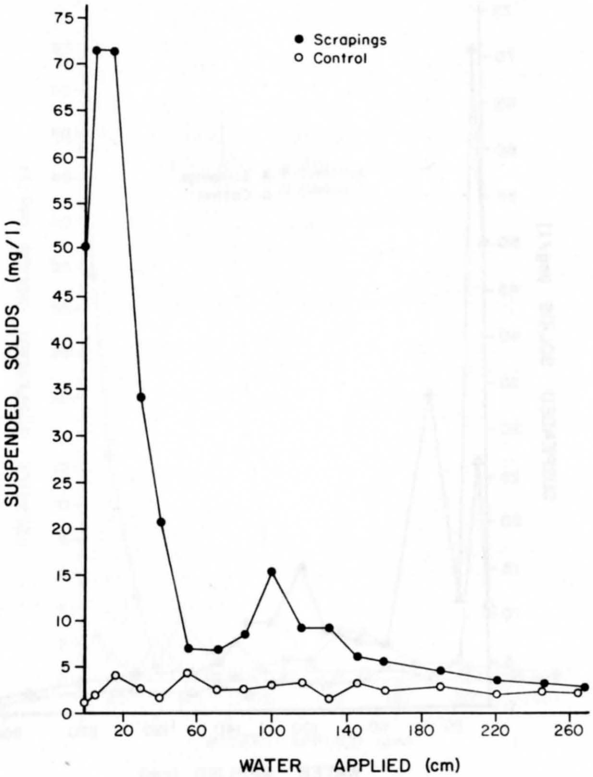

Figure 6. Comparison of leachate total suspended solids concentration for the control and experimental basins with 46 cm (18.1 in.) of filter sand.

the basin with 46 cm (18.1 in.) of spent filter sand, the initial leachate suspended solids concentration reached 71.2 mg/l after 30 cm (11.8 in.) of water had been applied. However, the concentration had reduced to 7.1 mg/l after application of 55 cm (21.7 in.) of water. Prior to the addition of 55 cm (21.7 in.) of water, the rate of decrease of leachate suspended solids concentration for the basin with 46 cm (18.1 in.) of spent filter sand was 2.6 mg/l of suspended solids per cm of applied water.

The reduction in leachate suspended solids concentrations for the basins containing 21 cm (8.3 in.) and 12 cm (4.7 in.) of spent filter sand is shown graphically in Figures 7 and 8 respectively. The sharp increases in leachate suspended solids concentration are due to disturbances near the effluent sampling tubes and are not representative of the total process.

As shown in Table 4, all basins maintained leachate suspended solids of less than 30 mg/l after 55 cm (21.7 in.) of water had been applied. However, increasing amounts of applied water were required to produce spent sand leachate concentrations equivalent to the control basin leachate. The amount of applied water required was directly related to spent filter sand depth. The deeper the spent filter sand the greater the amount of water required to produce a leachate quality equivalent to the control basin.

Based on the ratio of volume of applied water to volume of sand to produce a leachate with suspended solids concentrations less than 5 mg/l, a depth of spent filter sand of 12 cm (4.7 in.) appears to be the best design value. However, the impact of disturbances near the effluent sampling tubes could alter the effluent suspended solids easily and therefore should be approached with caution as a reliable index for design.

Volatile suspended solids. The leachate volatile suspended solids concentrations for both the control and experimental basins produced a pattern similar to that shown for leachate suspended solids concentrations. A comparison between the control and experimental basin leachate volatile suspended solids concentration for various depths of filter sand is shown in Figures 9, 10, and 11. A complete listing of the data is presented in Appendix A, Tables 14 to 30.

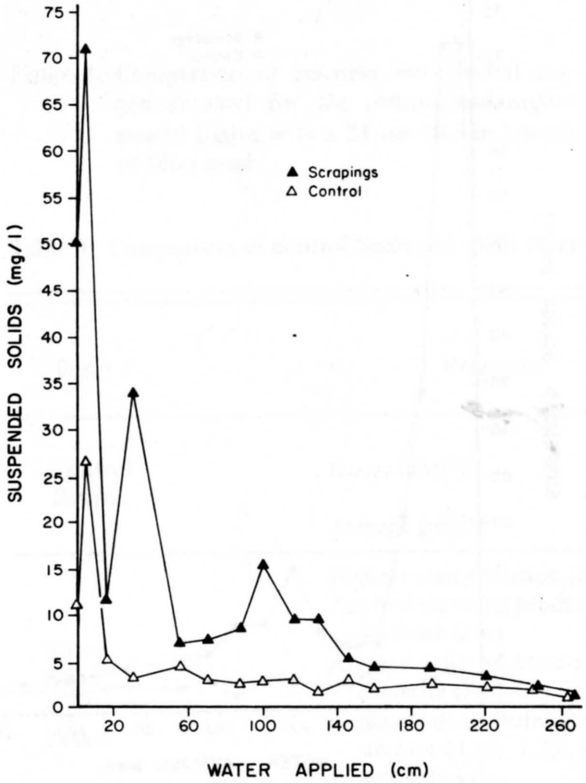

Figure 7. Comparison of leachate total suspended solids concentration for the control and experimental basins with 21 cm (8.3 in.) of filter sand.

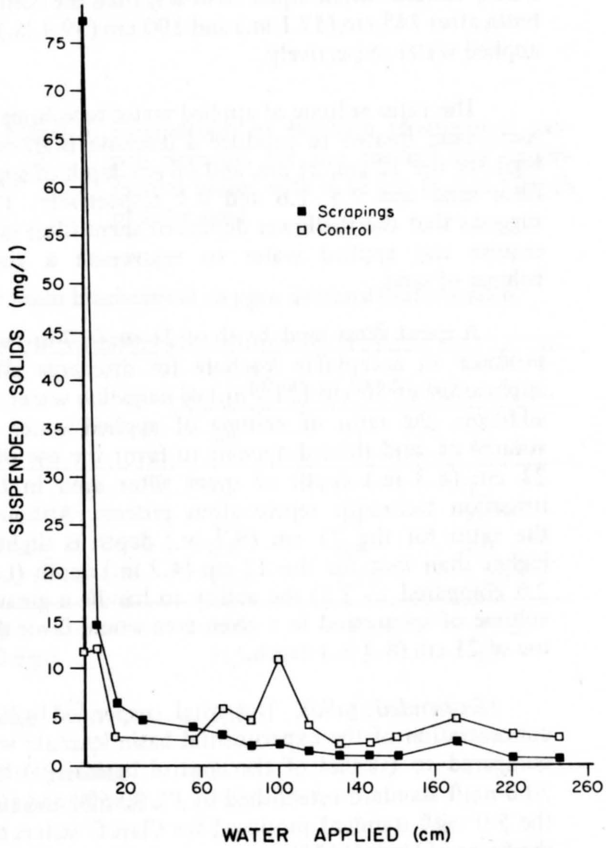

Figure 8. Comparison of leachate total suspended solids concentration for the control and experimental basins with 12 cm (4.7 in.) of filter sand.

Table 4. Comparison of control basin and spent filter sand basin total suspended solids performance.

Basin	Parameter	Depth of Sand (cm)		
		46	21	12
Control basins	Range (mg/l)	4.5 to 1.4	27.6 to < 1.73	12.0 to 2.01
	Average (mg/l)	2.82	5.01	5.46
Spent filter sand basins	Highest concentration (mg/l)	71.2	65.9	78.7
	Applied water to produce 30 mg/l leachate (cm)	55	15	5
	Applied water to produce 5 mg/l leachate (cm)	190	220	30
	Centimeters of water applied to produce average (2.82, 5.01, 5.46 mg/l) control leachate value	270	190	30
	Ratio of liters of applied water: liter of sand needed to produce 5 mg/l	4.1	8.9	2.5

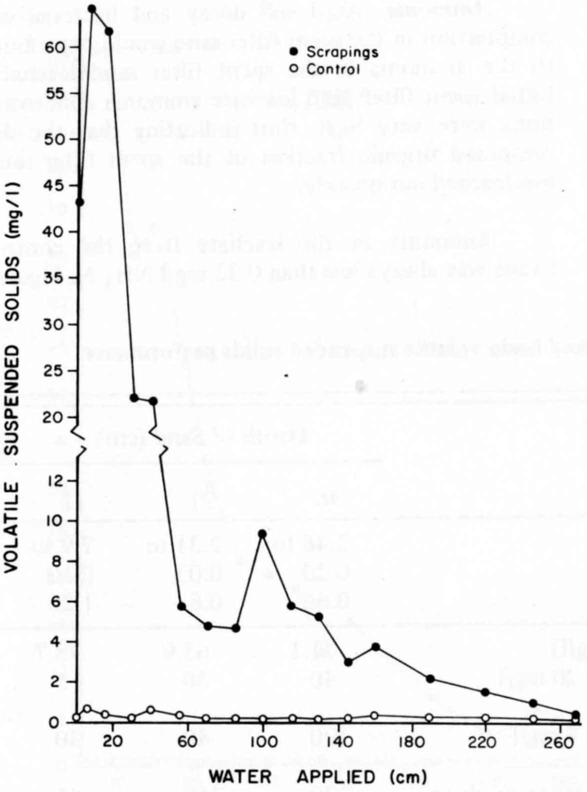

Figure 9. Comparison of leachate volatile suspended solids concentration for the control and experimental basins with 46 cm (18.1 in.) of filter sand.

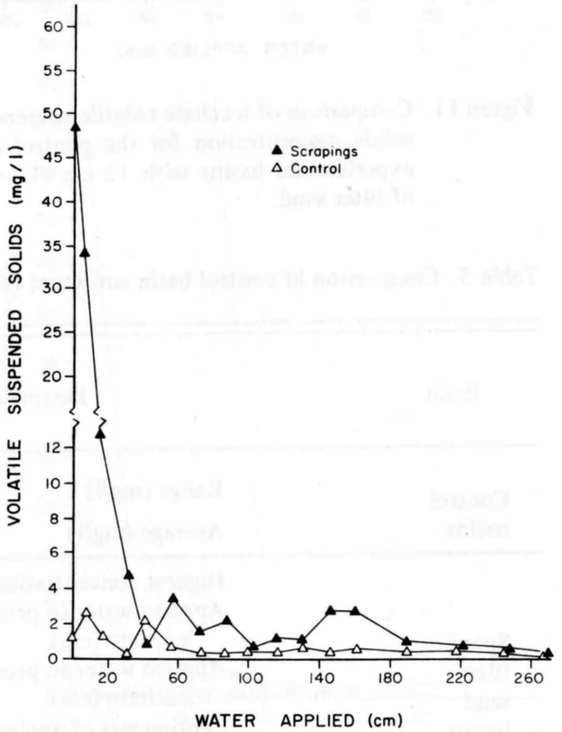

Figure 10. Comparison of leachate volatile suspended solids concentration for the control and experimental basins with 21 cm (8.3 in.) of filter sand.

As reported in Table 5, average leachate volatile suspended solids concentrations from the control basin were all less than 2.0 mg/l. Initial leachate volatile suspended solids for the experimental basins with 46 cm, 21 cm, and 12 cm (18.1, 8.3 and 4.7 in.) of spent filter sand were 68.2 mg/l, 48.2 mg/l and 36.9 mg/l respectively.

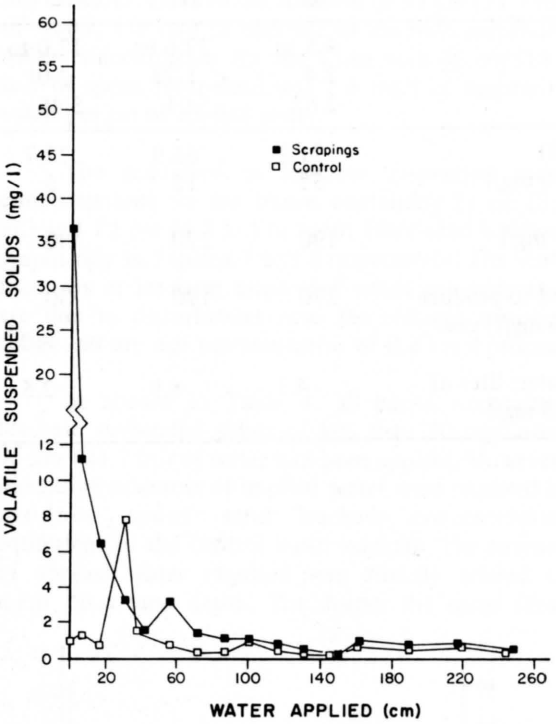

Figure 11. Comparison of leachate volatile suspended solids concentration for the control and experimental basins with 12 cm (4.7 in.) of filter sand.

As reported in Table 5 the experimental basin with 46 cm (18.1 in.) of spent filter sand required 4.1 liters of water for every liter of sand before leachate VSS concentrations remained below 4 mg/l. The 21 cm (8.3 in.) depth of spent filter sand required only 1.9 liters of water per liter of sand before effluent VSS concentration remained below 4 mg/l. The ratio of water to sand for the 12 cm (4.7 in.) depth of spent filter sand was 2.5 liters per liter. The 46 cm (18.1 in.) depth of spent filter sand leachate was less than 4 mg/l VSS after 130 cm (51.2 in.) of water had been applied. The 21 cm and 12 cm (8.3 and 4.7 in.) depth of spent filter sand leachate was less than 4 mg/l after 40 cm (15.7 in.) of water had been applied.

Reduction in leachate volatile suspended solids concentrations was more rapid than reduction in BOD_5 or suspended solids. Again it appears that a 21 cm (8.3 in.) depth of spent filter sand provides the best value for design of the rejuvenation process.

Ammonia. Algal cell decay and bacterial decomposition in the spent filter sand would contribute to the ammonia in the spent filter sand leachate. Initial spent filter sand leachate ammonia concentrations were very high, thus indicating that the decomposed organic fraction of the spent filter sand was leached out quickly.

Ammonia in the leachate from the control basins was always less than 0.32 mg/l NH_3-N. Figures

Table 5. Comparison of control basin and spent filter sand basin volatile suspended solids performance.

Basin	Parameter	Depth of Sand (cm)		
		46	21	12
Control basins	Range (mg/l)	2.46 to 0.20	2.31 to 0.03	7.9 to 0.10
	Average (mg/l)	0.66	0.8	1.26
Spent filter sand basins	Highest concentration (mg/l)	71.1	65.9	78.7
	Applied water to produce 20 mg/l leachate (cm)	40	30	5
	Applied water to produce 4 mg/l leachate (cm)	190	40	30
	Centimeters of applied water to produce average (0.66, 0.8, 1.26 mg/l) control leachate value	270	245	85
	Ratio of liters of applied water: liter of sand needed to produce 4 mg/l	4.1	1.9	2.5

12, 13, and 14 show graphically the leachate ammonia concentrations for both the control and experimental basins as a function of water applied to the basins. A complete summary of the data is in Appendix A, Tables 14 to 30.

Initially the ammonia concentration in the leachate of the basin with 46 cm (18.1 in.) of spent filter sand was 105 mg/l NH_3-N and after 5 cm (2 in.) of water had been applied the concentration exceeded 188 mg/l NH_3-N. Until 115 cm (46.3 in.) of water had been applied the ammonia concentration from this basin was "washed out" at the rate of 1.5 mg/l NH_3-N per cm of water applied. After 145 cm (57.1 in.) of water had been applied the rate slowed to 0.087 mg/l NH_3-N per cm of water applied. This basin's leachate never did reach an ammonia concentration of less than 1 mg/l. Even after 270 cm (105 in.) of water had been applied to the basin, 4.5 mg/l NH_3-N was remaining in the leachate.

The basin with 21 cm (8.3 in.) of spent filter sand had a somewhat lower leachate ammonia concentration. The initial value of 68.4 mg/l NH_3-N was reduced to 3.3 mg/l NH_3-N after 55 cm (21.7 in.) of water had been applied. This resulted in a removal rate of 1.2 mg/l NH_3-N per cm of water applied. After 130 cm (51.2 in.) of water had percolated through the 21 cm (8.3 in.) sand depth basin the NH_3-N leachate concentration was less than 0.43 mg/l NH_3-N, and when the experiment was terminated the concentration of NH_3-N was only 0.173 mg/l NH_3-N.

The removal of ammonia from the basin with 12 cm (4.7 in.) of spent filter sand was much the same as the other experimental basins except for a few sharp increases in the ammonia that occurred at 15 cm (5.9 in.) of applied water and at 40 cm (15.8 in.) of applied water (see Figure 14). Because this particular basin had a high rate of water passing through the effluent tubes, these peaks may reflect unusually large amounts of ammonia being carried with this water. The 12 cm (4.7 in.) depth basin leachate initially contained 81.2 mg/l NH_3-N but after only 70 cm (27.6 in.) of applied water the concentrations reduced to 1.1 mg/l NH_3-N. After 245 cm (96.5 in.) of water had been applied the ammonia concentration was as low as 0.031 mg/l NH_3-N.

As shown in Table 6, the experimental basin with 12 cm (4.7 in.) of spent filter sand required 9.4

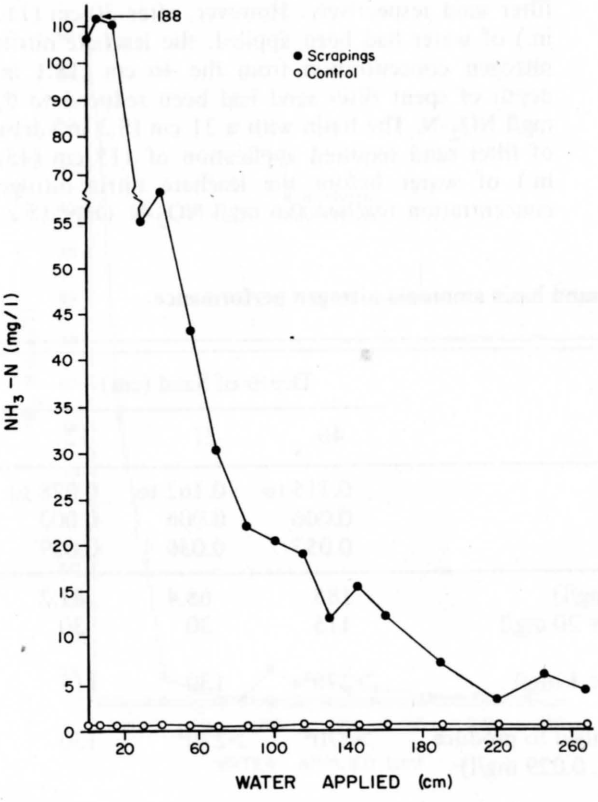

Figure 12. Comparison of leachate ammonia-nitrogen concentration for the control and experimental basins with 46 cm (18.1 in.) of filter sand.

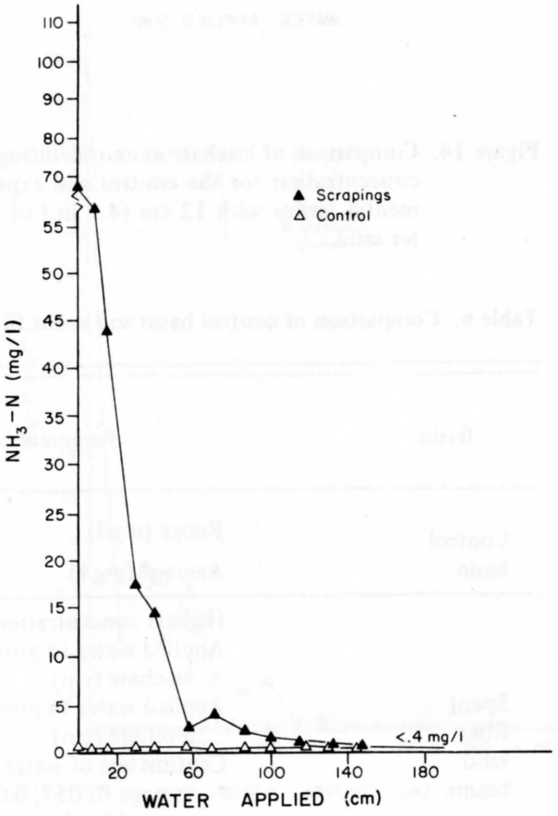

Figure 13. Comparison of leachate ammonia-nitrogen concentration for the control and experimental basins with 21 cm (8.3 in.) of filter sand.

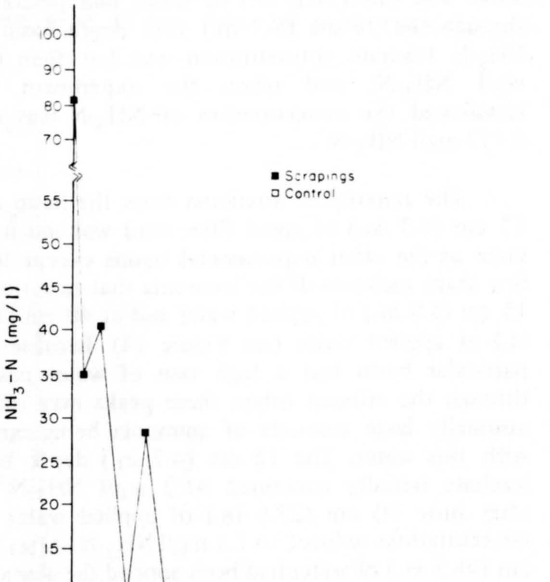

Figure 14. Comparison of leachate ammonia-nitrogen concentration for the control and experimental basins with 12 cm (4.7 in.) of filter sand.

liters of water for every liter of sand to achieve leachate ammonia concentrations of less than 1 mg/l NH_3-N. The experimental basin with 21 cm (8.3 in.) of spent filter sand required a 6.1 ratio of water to sand to reduce leachate ammonia concentrations to a similar level. While the experimental basin with 46 cm of spent filter sand never achieved this level, it appears that ammonia concentrations will be of little concern after 70 cm (27.6 in.) of water have been applied to a basin with a depth of filter sand near 21 cm (8.3 in.).

Nitrite. A comparison of the control and experimental basin leachate nitrite-nitrogen (NO_2-N) concentrations are shown graphically in Figures 15, 16, and 17. A complete listing of the data is in Appendix A, Tables 14 to 30. The control basin leachate nitrite-nitrogen concentrations were very low through the entire study. As reported in Table 7, the average control basin leachate nitrite-nitrogen concentrations for all depths of filter sand ranged from 0.0036 mg/l NO_2-N to 0.0042 mg/l NO_2-N.

The initial concentration of nitrite-nitrogen in the experimental basins were 57.9 mg/l NO_2-N, 72.9 mg/l NO_2-N and 49.0 mg/l NO_2-N for the 46 cm, 21 cm, and 12 cm (18.1, 8.3 and 4.7 in.) depth of spent filter sand respectively. However, after 30 cm (11.8 in.) of water had been applied, the leachate nitrite-nitrogen concentration from the 46 cm (18.1 in.) depth of spent filter sand had been reduced to 0.6 mg/l NO_2-N. The basin with a 21 cm (8.3 in.) depth of filter sand required application of 115 cm (45.3 in.) of water before the leachate nitrite-nitrogen concentration reached 0.6 mg/l NO_2-N. Only 15 cm

Table 6. Comparison of control basin and spent filter sand basin ammonia-nitrogen performance.

Basin	Parameter	Depth of Sand (cm)		
		46	21	12
Control basin	Range (mg/l)	0.315 to 0.006	0.162 to 0.006	0.078 to 0.003
	Average (mg/l)	0.057	0.036	0.029
Spent filter sand basins	Highest concentration (mg/l)	188	68.4	81.2
	Applied water to produce 20 mg/l leachate (cm)	115	30	30
	Applied water to produce 1 mg/l leachate (cm)	>270[a]	130	115
	Centimeters of water applied to produce average (0.057, 0.036, 0.029 mg/l) control leachate value	>270[a]	>270[a]	130
	Ratio of liters of applied water: liter of sand needed to produce 1 mg/l NH_3-N	> 5.8[a]	6.1	9.4

[a] Leachate did not reach stated value.

(5.9 in.) of applied water was required to reduce the nitrite-nitrogen concentration in the leachate from the basin with 12 cm (4.7 in.) of spent filter sand to 0.178 mg/l NO_2-N. A comparison of Figures 15, 16 and 17 indicates that reduction in leachate nitrite-nitrogen concentration occurs more rapidly with shallower depths of spent filter sand.

As shown in Figure 17, a substantial increase in nitrite-nitrogen concentration occurred in the leachate from the 12 cm (4.7 in.) depth of spent filter sand after approximately 15 cm (5.9 in.) of water had been applied. This increase may be due to an increase in algal cellular decay within the spent filter sand, thus releasing a significant quantity of oxidizable nitrogen. Because this phenomenon was not observed in any of the other basins it may be due to the nature of the 12 cm (4.7 in.) basin. This shallow basin could warm up faster than the basins with greater volumes. The resulting warmer environment could result in a superior environment for *Nitrosomonas* and hence the greater NO_2-N concentration in the leachate.

As reported in Table 7, the ratio of applied water to rejuvenated sand was smallest for the 46 cm (18.1 in.) depth of spent filter sand. The ratio for the 46 cm (18.1 in.) depth of spent filter sand was 4.1, while the ratio for the 12 cm (4.7 in.) depth of spent filter sand was 8.2. This would indicate that a greater depth of spent filter sand is a more desirable nitrite-nitrogen performance than a shallow depth of spent filter sand.

Nitrate. A comparison of the leachate nitrate-nitrogen concentrations for the control and experimental basins is shown graphically in Figures 18, 19, and 20. A summary of the complete nitrate-nitrogen data is recorded in Appendix A, Tables 14 to 30.

The control basin leachate nitrate-nitrogen concentrations never exceeded 0.6 mg/l NO_3-N. As reported in Table 8, the average leachate nitrate-nitrogen concentration for the control basins with 46 cm, 21 cm, and 12 cm (18.1, 8.3, and 4.7 in.) of spent filter sand were 0.258 mg/l NO_3-N, 0.278 mg/l NO_3-N and 0.255 mg/l NO_3-N respectively. The standard deviations for the control basins with 46 cm, 21 cm, and 12 cm of spent filter sand were respectively 0.130, 0.104, and 0.100. These values indicate that 95 percent of all nitrate-nitrogen

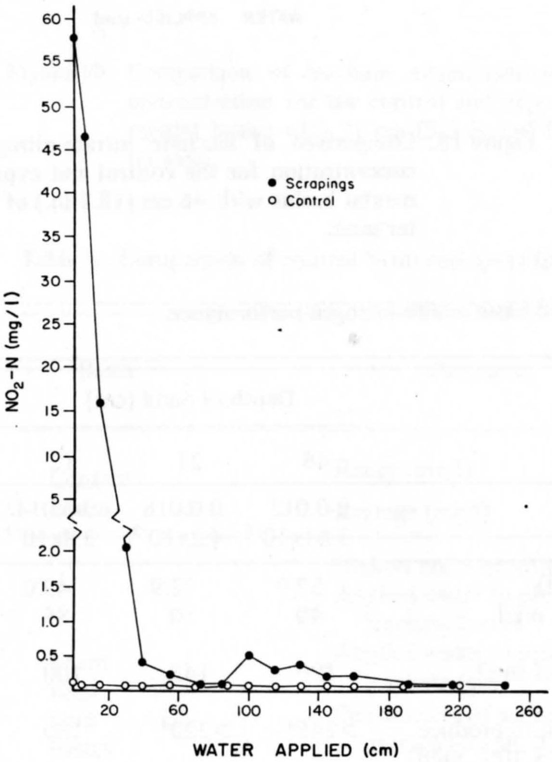

Figure 15. Comparison of leachate nitrite-nitrogen concentration for the control and experimental basins with 46 cm (18.1 in.) of filter sand.

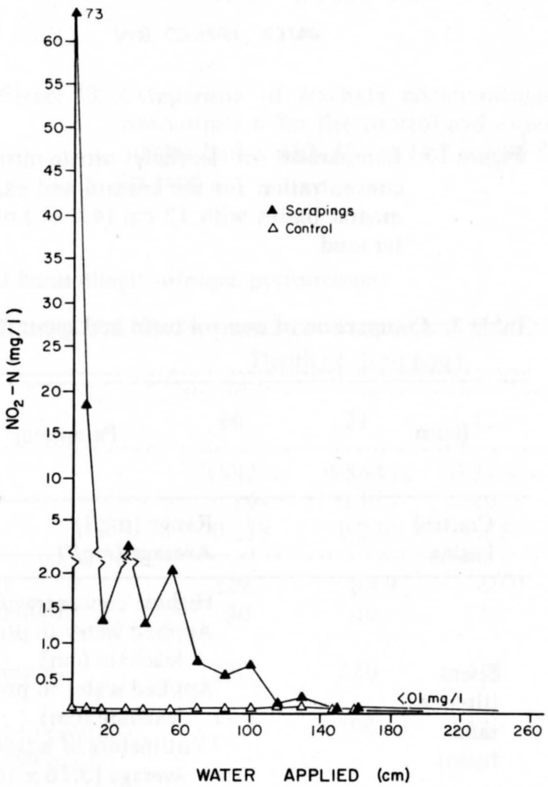

Figure 16. Comparison of leachate nitrite-nitrogen concentration for the control and experimental basins with 21 cm (8.3 in.) of filter sand.

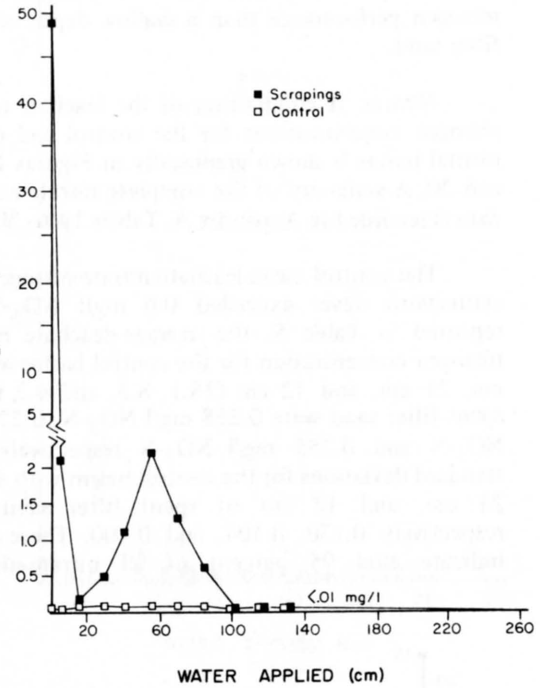

Figure 17. Comparison of leachate nitrite-nitrogen concentration for the control and experimental basins with 12 cm (4.7 in.) of filter sand.

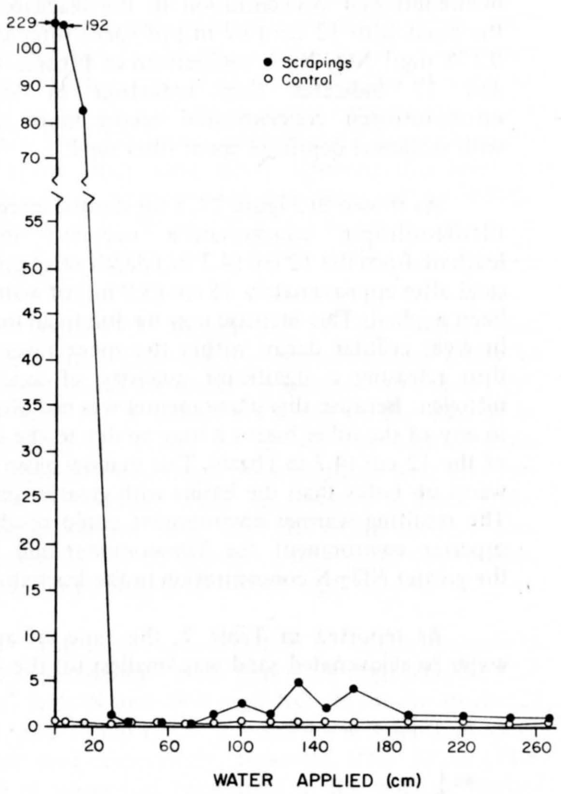

Figure 18. Comparison of leachate nitrate-nitrogen concentration for the control and experimental basins with 46 cm (18.1 in.) of filter sand.

Table 7. Comparison of control basin and spent filter sand basin nitrite-nitrogen performance.

Basin	Parameter	Depth of Sand (cm)		
		46	21	12
Control basins	Range (mg/l)	0-0.012	0-0.018	0-0.014
	Average (mg/l)	3.61×10^{-3}	4.2×10^{-3}	3.8×10^{-3}
Spent filter sand basins	Highest concentration (mg/l)	57.9	72.9	49.0
	Applied water to produce 1 mg/l leachate (cm)	40	70	85
	Applied water to produce 0.1 mg/l leachate (cm)	190	145	100
	Centimeters of water applied to produce average (3.16×10^{-3}, 3.8×10^{-3}, mg/l) control leachate values	>245[a]	>220[a]	160
	Ratio of liters of applied water: liter of sand needed to produce 0.1 mg NO_2-N	4.1	6.8	8.2

[a] Leachate did not reach stated value.

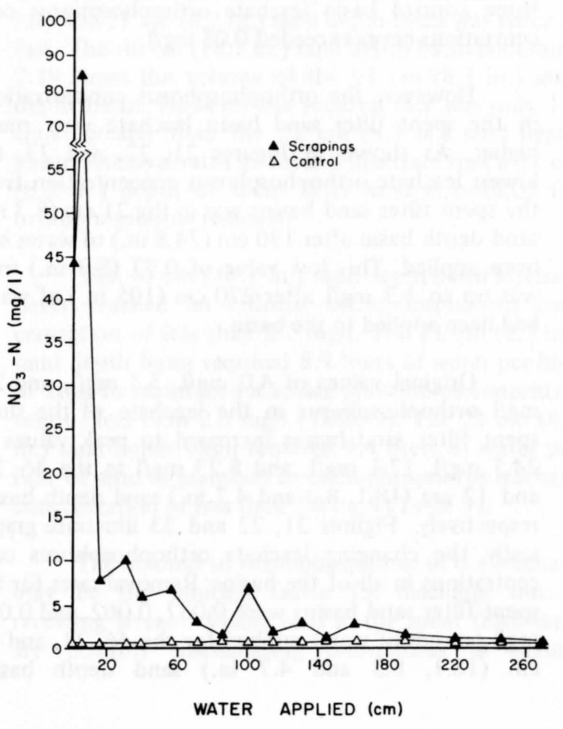

Figure 19. Comparison of leachate nitrate-nitrogen concentration for the control and experimental basins with 21 cm (8.3 in.) of filter sand.

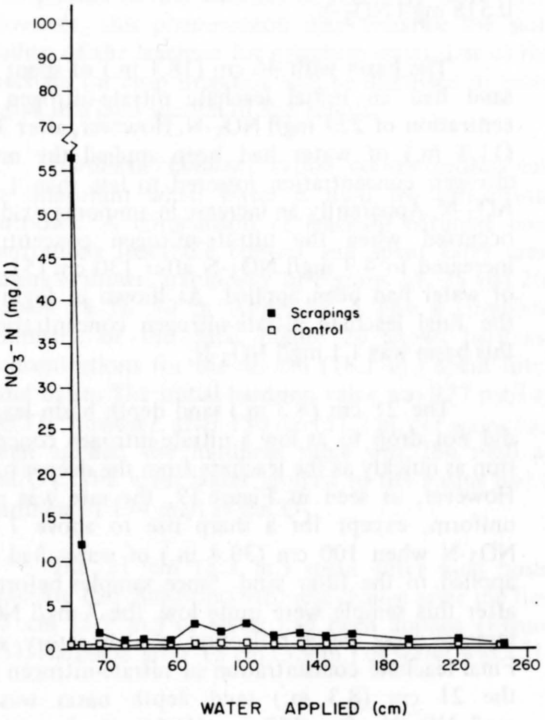

Figure 20. Comparison of leachate nitrate-nitrogen concentration for the control and experimental basins with 12 cm (4.7 in.) of filter sand.

Table 8. Comparison of control basin and spent filter sand basin nitrate-nitrogen performance.

Basin	Parameter	Depth of Sand (cm)		
		46	21	12
Control basins	Range (mg/l)	0.582 to 0.199	0.564 to 0.173	0.519 to 0.021
	Average (mg/l)	0.258	0.278	0.259
Spent filter sand basins	Highest concentration (mg/l)	229	84.9	60.9
	Applied water to produce 10 mg/l leachate (cm)	30	40	15
	Applied water to produce 2 mg/l leachate (cm)	190	220	115
	Centimeters of water applied to produce average (0.258, 0.278, 0.259 mg/l) control leachate value	>270[a]	190	130
	Ratio of liters of applied water: liter of sand needed to produce 2 mg/l NO_3-N.	4.1	10.3	9.4

[a] Leachate did not reach stated value.

leachate concentrations from the control basins were encompassed in a range of 0.001 mg/l NO_3-N to 0.518 mg/l NO_3-N.

The basin with 46 cm (18.1 in.) of spent filter sand had an initial leachate nitrate-nitrogen concentration of 229 mg/l NO_3-N. However, after 30 cm (11.8 in.) of water had been applied the nitrate-nitrogen concentration lowered to less than 1 mg/l NO_3-N. Apparently an increase in ammonia oxidation occurred when the nitrate-ntirogen concentration increased to 4.9 mg/l NO_3-N after 130 cm (51.2 in.) of water had been applied. As shown in Figure 18, the final leachate nitrate-nitrogen concentration in this basin was 1.1 mg/l NO_3-N.

The 21 cm (8.3 in.) sand depth basin leachate did not drop to as low a nitrate-nitrogen concentration as quickly as the leachate from the deeper basins. However, as seen in Figure 19, the rate was more uniform, except for a sharp rise to above 7 mg/l NO_3-N when 100 cm (39.4 in.) of water had been applied to the filter sand. Since samples before and after this sample were quite low, the 7 mg/l NO_3-N increase may be a reflection of laboratory error. Final leachate concentration of nitrate-nitrogen from the 21 cm (8.3 in.) sand depth basin was 1.1 mg/l NO_3-N after 270 cm (105 in.) of water had been applied.

The 12 cm (4.7 in.) sand depth basin leachate had an initial nitrate-nitrogen concentration of 60.9 mg/l NO_3-N. After 30 cm (11.8 in.) of water had been applied to the basin, the leachate nitrate-nitrogen concentration was less than 1 mg/l NO_3-N. Final leachate nitrate-nitrogen concentration for the 12 cm (4.7 in.) sand depth basin was 0.094 mg/l NO_3-N after 245 cm (96.5 in.) of water had been applied. This value was less than the average value for the control basin leachate.

As reported in Table 8, before the leachate nitrate-nitrogen concentration remained below 10 mg/l NO_3-N, 0.64 liters of water per liter of sand was applied to the 46 cm (18.1 in.) sand depth basin. The ratios for the 21 and 12 cm (8.3 and 4.7 in.) sand depth basins were 1.9, and 1.2 respectively. Before the 21 cm (8.3 in.) sand depth basin leachate nitrate-nitrogen concentration remained below 2 mg/l NO_3-N, 10.3 liters of water per liter of sand was required. For the 46 cm (18.1 in.) and 12 cm (4.7 in.) sand depth basin this ratio was 9.4 and 4.1 respectively. Thus, for nitrate-ntirogen removal from the spent filter sand it appears that a deeper sand depth is desirable.

Orthophosphorus. A comparison of leachate orthophosphorus concentrations from the control and experimental basins is shown graphically in Figures 21, 22, and 23. A complete summary of the data appears in Appendix A, Tables 14 to 30. All three control basin leachate orthophosphorus concentrations never exceeded 0.05 mg/l.

However, the orthophosphorus concentrations in the spent filter sand basin leachate were much higher. As shown in Figures 21, 22, and 23, the lowest leachate orthophosphorus concentration from the spent filter sand basins was in the 21 cm (8.3 in.) sand depth basin after 190 cm (74.8 in.) of water had been applied. This low value of 0.77 (8.3 in.) mg/l was up to 1.3 mg/l after 270 cm (105 in.) of water had been applied to the basin.

Original values of 4.0 mg/l, 3.3 mg/l, and 2.8 mg/l orthophosphorus in the leachate of the three spent filter sand basins increased to peak values of 24.5 mg/l, 17.1 mg/l, and 8.23 mg/l in the 46, 21, and 12 cm (18.1, 8.3 and 4.7 in.) sand depth basins respectively. Figures 21, 22 and 23 illustrate graphically the changing leachate orthophosphorus concentrations in all of the basins. Removal rates for the spent filter sand basins were 0.087, 0.062, and 0.031 mg/l per cm of water applied for the 46, 21, and 12 cm (18.1, 8.3 and 4.7 in.) sand depth basins

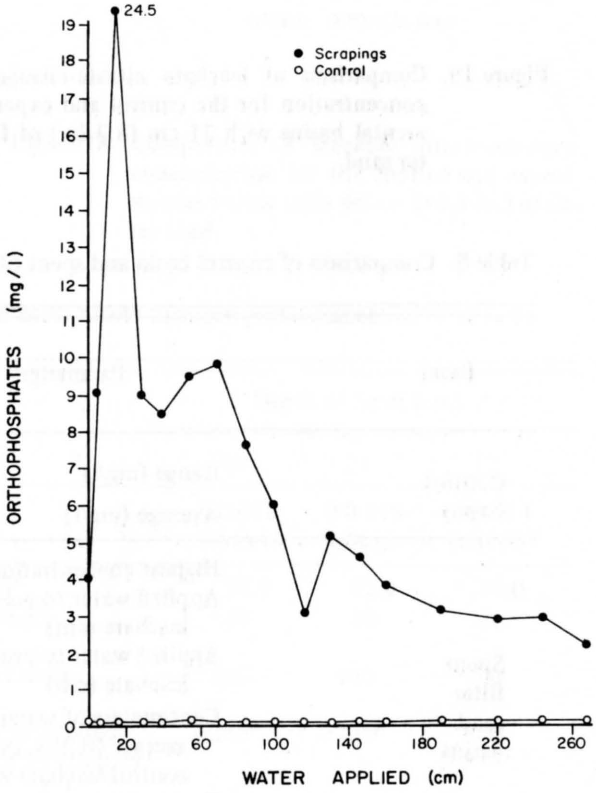

Figure 21. Comparison of leachate orthophosphorus concentration for the control and experimental basins with 46 cm (18.1 in.) of filter sand.

respectively. The 21 cm (8.3 in.) sand depth basin contained approximately 1.75 times the volume of the 12 cm (4.7 in.) sand depth basin yet the removal rate for 21 cm (8.3 in.) sand depth basin was twice as fast. The 46 cm (18.1 in.) sand depth basin contained 2.19 times the volume of the 21 cm (8.3 in.) sand depth basin. However the removal rate was only 1.4 times greater than the 21 cm (8.3 in.) sand depth basin. Removal rates in Table 8 illustrate that a 21 cm (8.3 in.) depth of spent filter sand is optimal for orthophosphorus removal.

The 46 cm (18.1 in.) sand depth basin leachate never reached an effluent orthophosphorous concentration of less than 2.2 mg/l. The 21 cm (8.3 in.) sand depth basin required 8.9 liters of water per liter of sand to maintain a leachate phosphorus concentration of less than 2.0 mg/l (Table 9). The 21 cm (8.3 in.) sand depth basin required 9.4 liters of water per liter of sand to maintain an orthophosphorus leachate concentration of less than 2.0 mg/l (Table 9).

The amount of orthophosphorus in the leachate may be the limiting factor for discharge into a receiving stream. Viable cells in the spent filter sand are possibly assimulating phosphorus in luxury amounts as it is released by dead cells in the spent filter sand. This storage by viable cells may release phosphorus to the leachate at relatively slow rates. However, this phenomenon may enhance the suitability of the leachate for irrigation water. Use of the leachate for crop irrigation will be discussed in more detail in a later section of this report.

Hardness. Divalent cation concentrations can be important when water is used for agricultural purposes. A comparison of leachate hardness concentrations from the control and spent filter sand basins is shown graphically in Figures 24, 25 and 26. Tables 14 to 30 in Appendix A give a complete summary of the data. Figure 24 shows hardness concentrations for the 46 cm (18.1 in.) spent filter sand basin. The initial hardness value was 977 mg/l as $CaCO_3$; however, after 130 cm (51.2 in.) of water had been applied the hardness value was 286 mg/l as $CaCO_3$. The wash water applied to the basins had a hardness of 174 mg/l as $CaCO_3$.

The 21 cm (8.3 in.) spent filter sand basin leachate had almost no hardness change after the first 15 cm (5.9 in.) of water had been applied (Figure 25). Hardness after 15 cm (5.9 in.) of water was 251

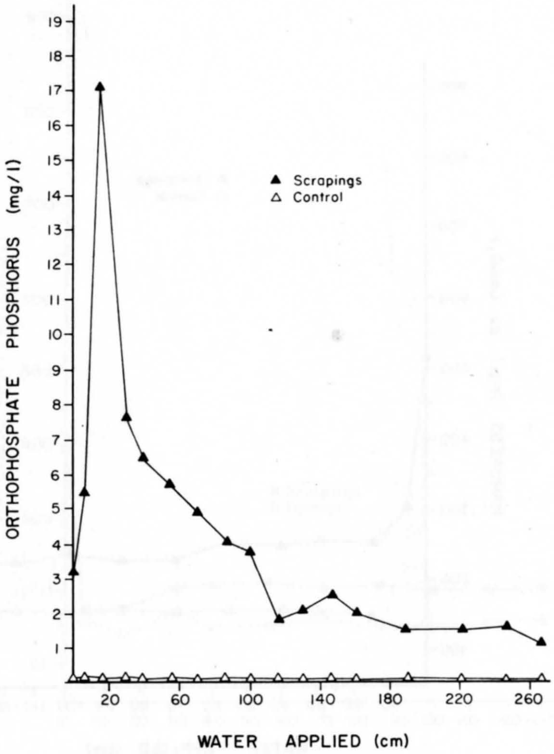

Figure 22. Comparison of leachate orthophosphorus concentration for the control and experimental basins with 21 cm (8.3 in.) of filter sand.

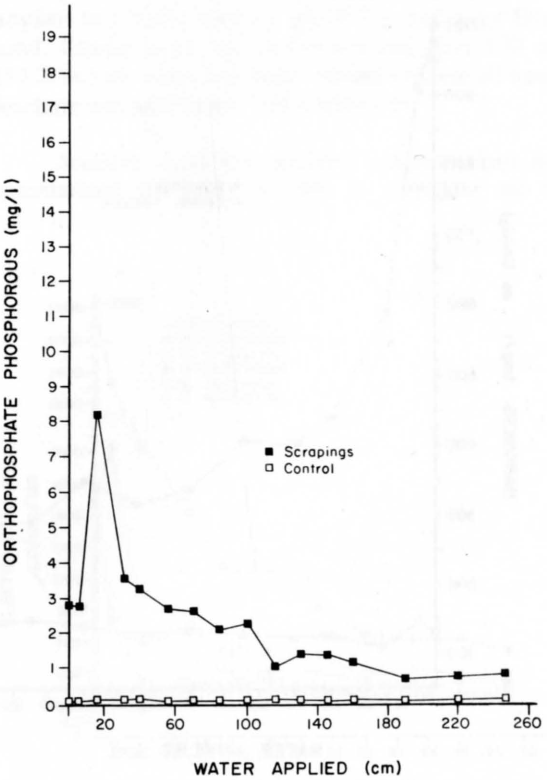

Figure 23. Comparison of leachate orthophosphorus concentration for the control and experimental basins with 12 cm (4.7 in.) of filter sand.

Table 9. Comparison of control basin and spent filter sand basin orthophosphorus performance.

Basin	Parameter	Depth of Sand (cm)		
		46	21	12
Control basins	Range (mg/l)	0.085 to 0.000	0.13 to 0.000	0.027 to 0.000
	Average (mg/l)	0.013	0.019	0.010
Spent filter sand basins	Highest concentration (mg/l)	24.5	17.1	8.2
	Applied water to produce 5 mg/l leachate (cm)	145	70	30
	Applied water to produce 2 mg/l leachate (cm)	>270[a]	190	115
	Centimeters of water applied to produce average (0.013, 0.019, 0.010 mg/l) control leachate value	>270[a]	>270[a]	>245[a]
	Ratio of liters of applied water: liter of sand to produce 2 mg/l orthophosphorus	> 5.8[a]	8.9	9.4
	Orthophosphorus removal rate (mg/l per cm of water applied)	0.087	0.062	0.031

[a] Leachate did not reach stated value.

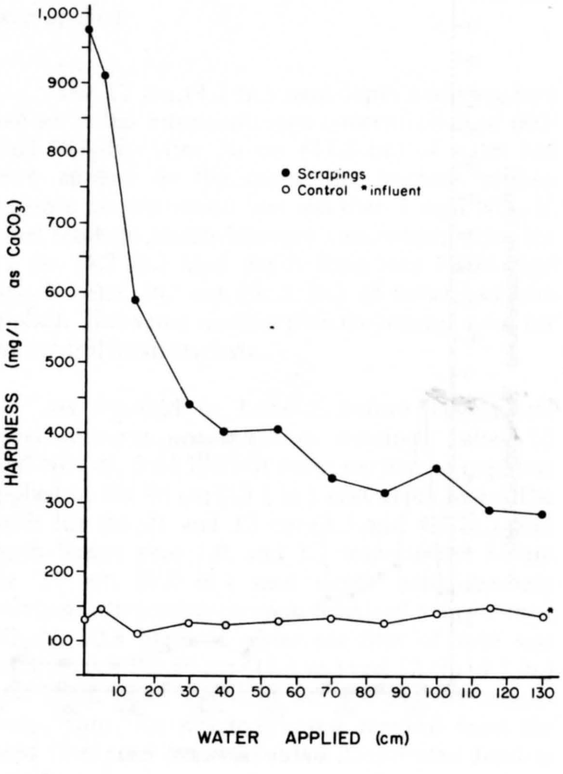

Figure 24. Comparison of leachate hardness concentration for the control and experimental basins with 46 cm (18.1 in.) of filter sand.

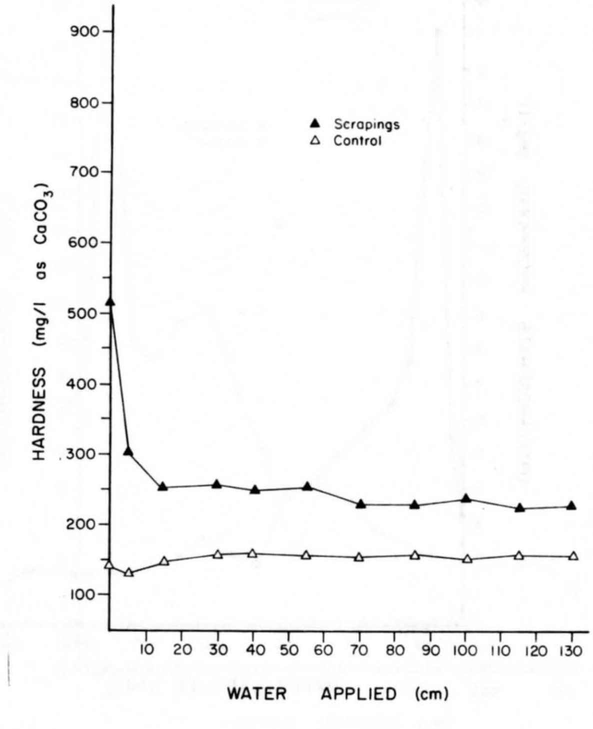

Figure 25. Comparison of leachate hardness concentration for the control and experimental basins with 21 cm (8.3 in.) of filter sand.

mg/l as $CaCO_3$ and after 115 cm (45.3 in.) of applied water more had passed through the basin, the hardness was lowered to 228 mg/l as $CaCO_3$. The shallower 12 cm (4.7 in.) spent filter sand basin leachate behaved in nearly the same manner (Figure 26) except a low hardness value of 164 mg/l as $CaCO_3$ was observed after 5 cm (2.0 in.) of water had been applied to the basin and after 130 cm (51.2 in.) had been applied the hardness was 202 mg/l as $CaCO_3$.

Control basin leachate hardness showed little change from a mean value of 146 mg/l. Determination of hardness was terminated after 130 cm (51.2 in.) of water had been applied because leachate hardness was sufficiently low enough to allow the use of the spent filter sand leachate as an irrigation water.

Conductivity. Conductivity was monitored because excessively saline waters cannot be used for irrigation. As shown in Figure 27, conductivity of the control basin leachate remained quite stable. The values of conductance in the leachate for all three control basins varied from 192 to 337 µmhos/cm.

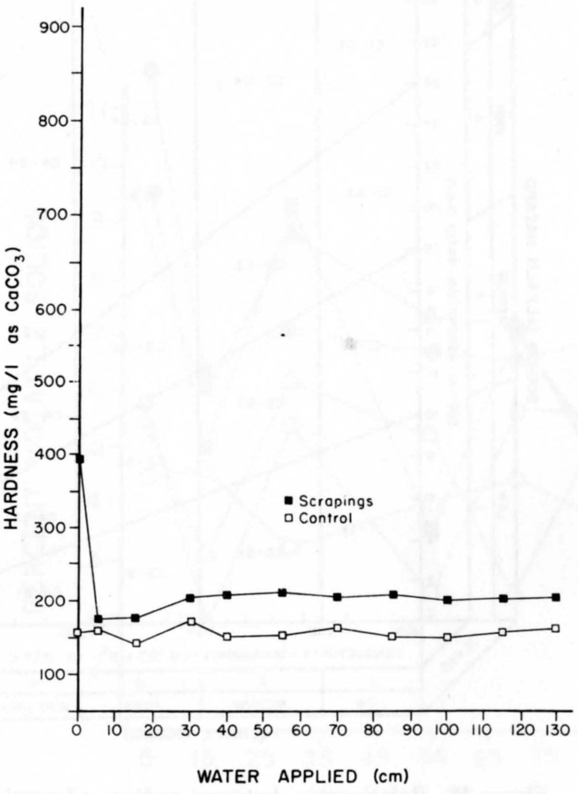

Figure 26. Comparison of leachate hardness concentration for the control and experimental basins with 12 cm (4.7 in.) of filter sand.

Figure 27 also shows how the effluent leachate from the three spent filter sand basins varied with amount of water applied. The 46 cm (18.1 in.) spent filter sand basin had an initial conductance of 3,607 µmhos/cm. After 85 cm (33.5 in.) of water had been applied the conductance was reduced to 633 µmhos/cm. This was also the first point less than 750 µmhos/cm. Final conductivity after 130 cm (51.2 in.) of water had been put through the basins was 559 µmhos/cm.

The 21 cm (8.3 in.) spent filter sand basin had a high conductance of 1,828 µmhos/cm after 5 cm (2.0 in.) of water had been applied. The 12 cm (4.7 in.) spent filter sand basin also maintained a conductance below 750 µmhos/cm after 5 cm (2.0 in.) of water had been applied to the basin. Final conductance for the 21 cm (8.3 in.) and 12 cm (4.7 in.) spent filter sand basins was 409 and 359 µmhos/cm respectively after 130 cm (51.2 in.) of water had been applied. Influent wash water had a conductance of 315 µmhos/cm.

Over one half of all irrigation waters in the western United States have conductance values between 250-750 µmhos/cm. The spent filter sand leachate is acceptable irrigation water in terms of salinity after 5.0 cm (2.0 in.) of water have been applied to a basin with 21 cm (8.3 in.) of spent filter sand. Conductivity was not monitored after 130 cm (51.2 in.) of water had been applied because all basin leachate was well below 750 µmhos/cm.

Sodium. Leachate sodium concentrations are summarized in Table 10 and a complete set of

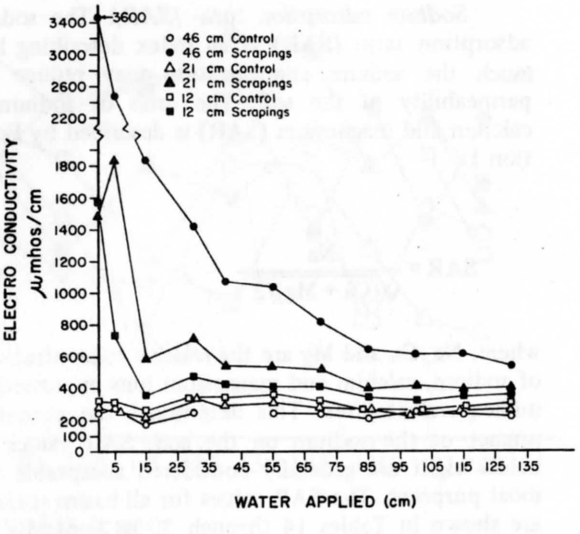

Figure 27. Comparison of leachate electroconductivity for the control and experimental basins.

Table 10. Leachate sodium concentrations.

Basin	Depth of Sand (cm)	Leachate Sodium Concentration, meq/l			
		Initial	Highest	Lowest	Final After 130 cm Applied Water
	46	0.252	0.252	0.043	0.050
Control	21	1.52	2.350	0.174	0.261
	12	0.144	0.652	0.043	0.130
Spent filter sand	46	3.04	3.04	0.050	0.050
	21	1.39	1.39	0.043	0.043
	12	1.22	1.22	0.043	0.043

cm = 0.39 inches.

leachate sodium values are recorded in Appendix A, Tables 14 to 30. In general leachate sodium concentrations were relatively low throughout the entire study. As shown in Table 10, initial leachate sodium concentrations ranged from 3.04 meq/l for the 46 cm (18.1 in.) spent filter sand depth basin to 0.252 meq/l for the 46 cm (18.1 in.) clean filter sand depth basin. In general, the leachate sodium concentration decreased with increasing application of water. The final leachate sodium concentrations ranged from 0.261 meq/l in the 46 cm (18.1 in.) spent filter sand depth basin to 0.043 meq/l in the 12 cm (4.7 in.) clean and spent filter sand depth basin. The significance of the leachate sodium concentration will be discussed in the following section on sodium adsorption ratio (SAR) and sodium hazard.

Sodium adsorption ratio (SAR). The sodium adsorption ratio (SAR) is an index describing how much the sodium concentration may reduce the permeability of the soil. The ratio of sodium to calcium and magnesium (SAR) is described by Equation 1

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}} \quad . \; . \; . \; . \; . \; . \; . \quad (1)$$

where, Na, Ca and Mg are the relative concentrations of sodium, calcium and magnesium ions expressed in milliequivalents/liter. This determines the potential impact of the sodium on the soil. SAR values of below eight are generally considered acceptable for most purposes. The SAR values for all basins studied are shown in Tables 14 through 30 in Appendix A. The SAR values for all basin leachates are less than 1.0. The average SAR for the spent filter sand basin leachates is 0.30 with a standard deviation of 0.26.

Figure 28 depicts the relationship between SAR and conductivity and indicates those soils for which a particular water can safely be used as an irrigation

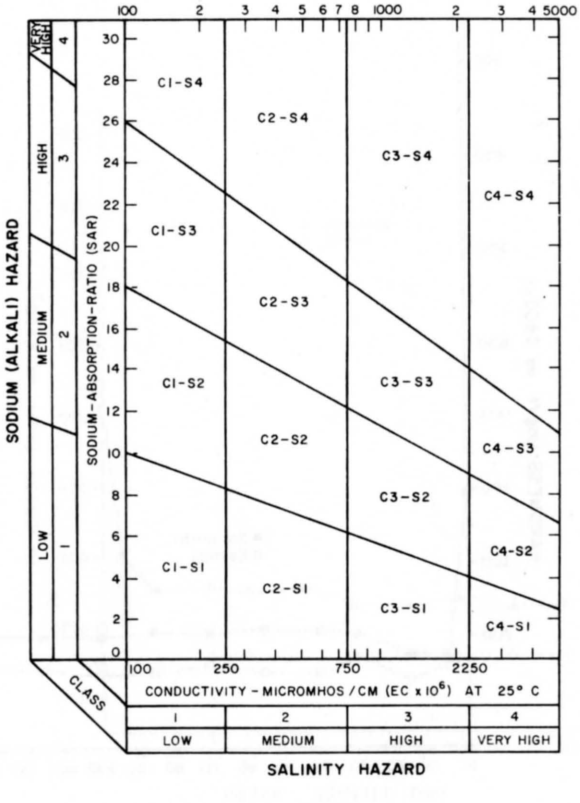

Figure 28. Relationship between sodium adsorption ratio (SAR) and conductivity indicating soil types on which spent filter sand leachate may be used as irrigation water. (Eldridge, 1960)

source. In general, as the SAR and conductivity of a particular water increases, the range of soils on which that water may be used for irrigation is reduced. Both the conductivity and SAR values for the spent filter sand leachate were relatively low through the entire study. Conductivity values were always less than 4,000 micromhos/cm (see Appendix A) and SAR values were never greater than 1.0. Under these conditions, Figure 28 indicates that the spent filter sand leachate is acceptable for irrigation on all S-1 type soils. These soils (S-1) are classified as sodium sensitive soils. Thus, the leachate is acceptable for use as irrigation water on all types of soil and for all types of crops, except those crops which are highly sodium sensitive.

Volatile solids. Figure 29 shows that the volatile solids content of sand from the control and experimental basins produced an irratic pattern. Best fit linear regression lines for the spent filter sand and control sand yielded r correlation coefficients of 0.19 and 0.21 and illustrate that the different lines produced by spent filter sand and control sand are not a reliable index of the difference in volatile content of the sand from the experimental and control basins. A two tailed students "t" test used to analyze the spent filter sand volatile solids mean value of 0.60 percent and the control volatile solid mean value of 0.48 percent showed that with 95 percent confidence these two means were different. Further analysis of the volatile solid data showed that with 95 percent confidence the volatile solid mean value of the spent filter sand and the mean of the control sand were the same when 30 cm (11.8 in.), 55 cm (21.6 in.), 85 cm (33.3 in.), 100 cm (39.3 in.), 130 cm (51.2 in.), 145 cm (57.1 in), 190 cm (74.8 in.), and 220 cm (86.6 in.) of water had been applied to the basins. These mean population values were not the same (with 95 percent confidence) when 5 cm (2.0 in.), 15 cm (5.9 in.), 70 cm (27.6 in.), 115 cm (45.3 in.), and 160 cm (64.0 in.) of water was applied. Initial volatile solids determinations were assumed to be in error because a very small sample size was used leading to a much higher volatile solids concentration in the sand on this initial date. The volatile solids data are summarized in Appendix A, Tables 14 to 30.

In summary, the volatile solids data fail to give a clear idea of when the sand from the plugged filters was clean. The inaccuracy associated with the test, stratification and uneven removal of volatile matter from the spent filter sand, and microbiological growth in the sand may all have contributed to the variation.

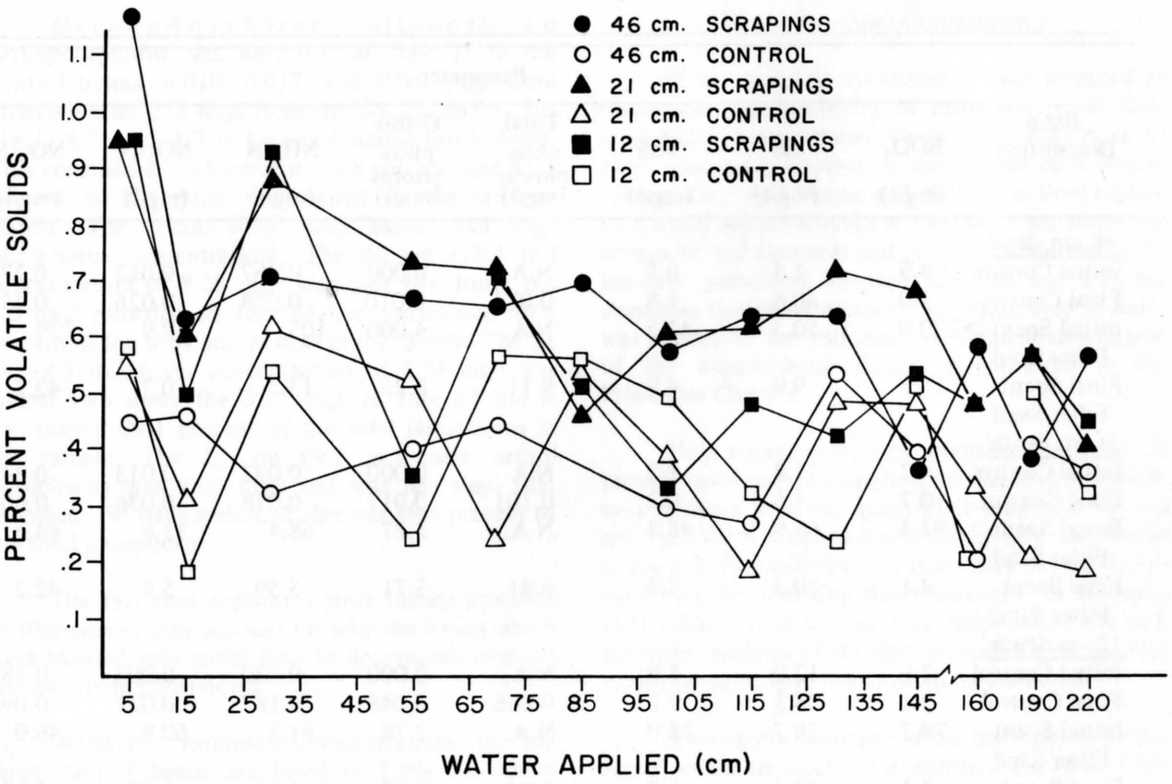

Figure 29. Percent volatile matter in control and experimental sand basins of indicated depth.

Part B: Natural exposure

General. Control basins and experimental basins with clean filter sand and spent filter sand in depths of 46 cm (18.1 in.), 21 cm (8.3 in.), and 12 cm (4.7 in.) were exposed to natural northern Utah weather conditions for 258 days to determine the feasibility of sand rejuvenation without supplemental water addition. The exposure period began July 25, 1975, and continued to April 8, 1976. A complete set of the data collected during this period is tabulated in Table 11.

Biochemical oxygen demand. The 46 cm (18.1 in.) basin control side had a BOD$_5$ of 1.0 mg/l while the side containing spent filter sand had 15.2 mg/l BOD$_5$. The 15.2 mg/l BOD$_5$ was only 5.6 percent of the original value of 270 mg/l shown by the 46 cm (18.1 in.) deep basin on July 25. The 21 cm (8.3 in.) basin BOD was 4.1 mg/l BOD$_5$ which was 4.4 percent of the original 93.4 mg/l BOD$_5$ observed in July. The 12 cm (4.7 in.) basin was only 2.7 percent of the 79.2 mg/l BOD$_5$ observed 258 days earlier; however, the 12 cm (4.7 in.) control was much higher than the control BOD of the other basins. This high control BOD of 3.1 mg/l in the shallowest basin was attributed to solar warm up which would help acquire a slightly higher bacteria growth than the deeper colder basins. The low spent filter sand BOD$_5$ however does not substantiate this hypothesis.

A major portion of the original BOD had been removed in 258 days. However, as more water is applied leachate may contain considerably more material that is bacterially oxidizable.

Suspended solids. Suspended solids were very high in the control basins. All the basins had higher suspended solid control concentrations than the suspended solids from the spent filter sand containing basins. These control concentrations of 30.8 mg/l, 21.6 mg/l, and 25.3 mg/l for the 46 cm, 21 cm, and 12 cm, (18.1, 8.3 and 4.7 in.) basins respectively represent the first washing of fines from the sand as seen with all sand media. The lower suspended solids of the spent filter sand basin may reflect the binding ability of the bacteria present in the media plus the fact that this material had been thoroughly washed while on the sand filter. Concentrations of 9.9 mg/l, 20.3 mg/l, and 13.3 mg/l were 19.7 percent, 30.8

Table 11. Comparison of control and experimental basin leachate after 258 day exposure to natural weather conditions.

Basin Description	Parameter							
	BOD$_5$ (mg/l)	SS (mg/l)	VSS (mg/l)	Total phosphorus (mg/l)	Orthophosphorus (mg/l)	NH$_3$-N (mg/l)	NO$_2$-N (mg/l)	NO$_3$-N (mg/l)
46 cm depth								
Initial Control	4.9	1.4	0.5	N.A.	0.000	0.067	0.012	0.270
Final Control	1.0	30.8	1.8	0.074	0.010	0.078	0.026	0.453
Initial Spent Filter Sand	$>$270.0	50.3	42.5	N.A.	4.000	105	57.9	229
Final Spent Filter Sand	15.2	9.9	4.9	9.11	8.25	13.3	10.2	42.2
21 cm depth								
Initial Control	4.2	11.4	1.2	N.A.	0.000	0.032	0.013	0.349
Final Control	0.7	21.6	0.2	0.101	0.017	0.078	0.036	0.603
Initial Spent Filter Sand	93.4	65.9	48.2	N.A.	3.27	68.4	72.9	44.6
Final Spent Filter Sand	4.1	20.3	2.9	6.41	5.71	5.59	5.9	42.2
12 cm depth								
Initial Control	2.6	12.0	1.0	N.A.	0.000	0.030	0.006	0.381
Final Control	3.1	25.3	1.2	0.056	0.048	0.187	0.032	0.098
Initial Spent Filter Sand	79.2	78.7	36.9	N.A.	2.78	81.2	60.9	49.0
Final Spent Filter Sand	2.1	13.3	1.7	2.94	2.62	2.86	2.63	2.67

N.A. = not available.

percent, and 16.9 percent of the values recorded 258 days earlier from spent sand filter sand leachate. Again, time removed over two thirds of the material but the remaining concentrations of suspended solids are excessively high for discharge into most streams.

Volatile suspended solids. Final effluent concentrations of volatile suspended solids as shown in Table 11 show that the 46 cm (18.1 in.) basin was only 11.5 percent of that recorded 258 days earlier. The 21 cm (8.3 in.) basin was 6.0 percent of the July 25 concentrations and the 1.7 mg/l in the 12 cm (4.7 in.) basin was 4.6 percent of that recorded over eight months earlier from the 12 cm (4.7 in.) basin containing spent sand filter scrapings.

Control concentrations for the three basins were quite low as would be expected, 1.8 mg/l for the 46 cm (18.1 in.) basin, 0.2 mg/l for the 21 cm (8.3 in.) basin and 1.2 mg/l in the 12 (4.7 in.) basin. The control values of volatile suspended solids 258 days earlier were much the same and can be seen in Table 11.

Total phosphorus. Total phosphorus was not analyzed for on July 25, 1975. Hence comparison is impossible. Total phosphorus data given in Table 11 will be discussed further in the orthophosphorus section.

Orthophosphorus. Although no orthophosphorus was detected on July 25 in the control basins, 0.010, 0.017, and 0.048 mg/l were observed after 258 days from the 46, 21, and 12 cm (18.1, 8.3, and 4.7 in.) control basins respectively. This constituted 13.5 percent, 16.8 percent, and 85.7 percent of the total phosphorus in the effluent waters. The spent filter sand basins had high phosphorus concentrations. The 46 cm (18.1 in.) concentration of 8.25 mg/l was over two times the 4.0 mg/l recorded on July 25 and constituted 90.6 percent of the total phosphorus in the sample. The 21 cm (8.3 in.) basin concentration of 5.71 mg/l was almost two times the 3.27 mg/l of July 25 and it constituted 89.1 percent of the total phosphorus in the sample. The 12 cm (4.7 in.) basin orthophosphorus was 2.62 mg/l and was less than that recorded 258 days earlier. It also was 89.1 percent of the total phosphorus.

The fact that organisms store luxury amounts of phosphorus may account for why the basins which were allowed substantial time to decompose organics released more phosphorus.

Ammonia. Ammonia concentrations for the three control basins are listed in Table 11. These values are over two times most of the control values of July 25 but are still quite low. The values of 13.3, 5.59, and 2.86 mg/l for the 46, 21, and 12 cm (18.1, 8.3, and 4.7 in.) basins are 12.7, 8.2, and 3.5 percent of the 10.5, 68.4, and 81.2 mg/l recorded over eight months previous. Again time and natural conditions reduced concentrations substantially but not to control levels.

Nitrite. Control concentrations of nitrite are recorded in Table 11 and are low. The 46 cm (18.1 in.) basin nitrite effluent leachate concentration was only 17.6 percent of the July 25 level. The 21 cm (8.3 in.) and 12 cm (4.7 in.) leachate concentrations were 8.1 percent and 5.4 percent of the July 25 concentrations. Nitrite behaved as most of the other parameters when exposed basins were analyzed. The nitrite concentrations are high and represent a potential nitrogenous BOD_5 that could be exerted in a receiving stream.

Nitrate. The control concentrations of 0.453 mg/l, 0.603 mg/l, and 0.098 mg/l are close to those for July 25. The 46 cm (18.1 in.) basin effluent of 42.2 mg/l is 18.4 percent of the concentration from the 46 cm (18.1 in.) basin in July. The 42.2 mg/l in the 21 cm (8.3 in.) basin however is 94.6 percent of the 44.6 mg/l recorded in July. Why so little decrease in nitrate is recorded for this case is not known; 2.63 mg/l nitrate was found in the 12 cm (4.7 in.) basin and this was 4.3 percent of that concentration of 258 day previous.

Phase II: Soil Conditioner

Phase II: "Soil Conditioner" was designed to determine that feasibility of using the spent filter sand as a soil conditioner. Three centimeters of spent filter sand were applied to the surface of a Parley, Nibley, Clay, and Draper soil. Water was then applied to the soil and an attempt was made to determine the change in soil chemical and physical properties as the leachate percolated through the soil and also the change in the leachate quality was monitored as water was applied to the lysimeters. A complete description of the experimental design is contained in the Procedure Chapter.

This experiment was orginally designed to provide necessary information on quantities of nutrients released from the spent filter sand into the soil and how these nutrient levels would vary with depth in the soil. The different soil types may have different capacities for retaining these nutrients. In addition, sand added to clay soils may help aerate the soil. However, analysis of the data indicated that none of these questions have been definitely answered.

A complete summary of the soil analysis before and after the six weeks of irrigation is shown in Table 12. In general, the data in Table 12 indicates that addition of the spent filter sand had little effect on the characteristics of the four soils studied. Due to

Table 12. Summary of Phase II: Soil Conditioner Data.

	pH	Salinity Conductance mmhos/cm	P ppm	K ppm	Texture (Est.)	Lime += Present 0,+,++	CEC meq/100 g	Exchangeable Na meq/100g	Extractable Na meq/100g	Water Soluble Na meq/100g	Moisture Saturation %	% Organics
Parley Before	7.9	0.6	21	490	SiL	13.1	17.4	0.2	0.2	<0.1	47	2.28
Parley Control Top	7.4	0.9	24.0	490	SiL	++	19.0	0.38	0.41	0.04	54.4	3.88
Parley Control Middle	7.3	2.4	29.0	490	SiL	++	20.5	0.36	0.41	0.05	51.0	4.21
Parley Sand Top	7.4	1.0	28.0	490	SiL	++	18.9	0.39	0.42	0.03	53.2	3.62
Parley Sand Middle	7.3	3.6	27.0	490	SiL	++	20.0	0.39	0.46	0.07	52.2	4.02
Nibley Before	7.6	1.5	16	410	Si	0.8	22.2	0.9	0.2	<0.1	47	1.31
Nibley Control Top	7.7	0.7	18.0	293	SiL	+	22.9	0.38	0.41	0.03	45.4	2.1
Nibley Control Middle	7.4	0.9	20.0	325	SiL	+	23.3	0.42	0.46	0.04	43.8	2.26
Nibley Sand Top	7.9	0.8	25.0	420	SiL	+	23.3	0.38	0.41	0.03	47.6	2.28
Clay Before	8.6	1.1	4.2	490	C	55.6	19.1	9.8	2.6	0.7	84	2.10
Clay Control Top	8.2	0.7	5	450	SiC	++	19.6	1.07	1.38	0.29	70.6	3.41
Clay Control Middle	8.3	1.7	19	370	SiL	++	20.5	2.23	3.04	0.81	69.8	3.90
Clay Sand Top	7.9	0.7	12.0	420	SiL	++	17.8	0.66	0.85	0.19	65.3	3.64
Clay Sand Middle	8.2	0.9	5.3	490	SiL	++	20.7	1.75	2.14	0.39	66.5	3.95
Draper Before	7.3	0.8	13	490	SiL	0.3	13.8	1.0	0.2	<0.1	47	1.91
Draper Control Top	7.3	0.5	21.0	310	SiL	+	13.2	0.47	0.50	0.03	50.6	3.12
Draper Control Middle	7.2	0.9	20.0	410	SiL	+	12.9	0.39	0.45	0.06	50.1	3.62
Draper Sand Top	7.6	0.5	33.0	293	SiL	++	11.9	0.38	0.40	0.02	52.0	2.98
Draper Sand Middle	6.9	0.3	19.0	300	SiL	+	9.7	0.37	0.40	0.03	40.8	2.36

the limited number of soil samples analyzed and the number of sample replicates taken, it is difficult to speculate on the significance of these results. However, the data do provide an insight into possible interactions. Thus a brief summary and discussion of the data is presented. Further research is required to determine the exact effect of addition of spent filter sand on soil properties.

Soil properties

pH. The pH of the soil before and after the eight weeks of irrigation with the addition of spent filter sand did not change to any extent for any of the four soil types. The greatest change in soil pH occurred in the Parley soil. Originally the Parley soil had a pH of 7.9 (Table 12). After the irrigation experiment the pH was near 7.4. Some of the salts leached out by the sand may have had a buffering effect on the pH but control pH levels were also near 7.4.

Salinity. The electroconductivity of the four soils did not change significantly throughout the experiment (Table 12). The Parley soil appears to have been affected slightly by the spent filter sand. The electroconductivity seems to have increased in the Parley soil. An original value of 0.6 mmhos/cm was increased to an average electroconductivity of 1.7 mmhos/cm. This increase was noted in both the control and spent filter sand lysimeters and therefore a definite change in soil conductivity due to the spent filter sand cannot be shown. The change may be due to the hardness of the irrigation water used for the experiment.

Phosphorus. Phosphorus was expected to increase with all lysimeters that contained spent filter sand (Table 12). The greatest change in soil phosphorus occurred in the Clay and Draper soils. However, the control lysimeters also showed an increase in phosphorus and hence phosphorus increase cannot be attributed to the spent filter sand.

Potassium. More potassium apparently is present in the Nibley soil after application of the spent filter sand (Table 12). An initial concentration of 410 ppm increased to 420 ppm at the top of the spent filter sand lysimeter and the 20 cm depth of that lysimeter had a concentration of 480 ppm. The control lysimeter had less potassium than the spent filter sand lysimeter, the control lysimeter had 293 ppm in the top layer with 325 ppm at the 20 cm depth. The Draper soil, however, seems to show a decrease in the amount of potassium retained in the soil. Initially 490 ppm or more of potassium was measured in the Draper soil. After eight weeks of irrigation, the Draper soil with spent filter sand contained 300 ppm of potassium, while the lysimeter without spent filter sand contained 310 ppm and 410 ppm. The hardness of the water may have initiated exchange of some of the soil potassium but with the short duration of this experiment measurable change would not be expected.

Sodium. Table 12 indicates the various forms of sodium analyzed. Sodium values did not change greatly with time and were not significantly affected by the addition of the spent filter sand.

Moisture. Except for the Clay soil, the ability of the four different soils to maintain moisture was not altered with the addition of spent filter sand. However, the Clay control lysimeter also produced lower moisture saturation values after the addition of the spent filter sand. Lab technique is possibly responsible for this change as the control and spent filter sand lysimeter moisture values are nearly identical.

Organic content. All soils showed an increase in the amount of organic material present after six weeks of irrigation. Both control and spent filter sand lysimeters showed slightly more than a 1 percent increase in organic material content after the eight week irrigation period. Differences between control and spent filter sand lysimeters are not apparent nor is there evidence to indicate that the soil directly below the spent filter sand contained more organic matter after the leaching of spent filter sand for the eight weeks.

Leachate quality

General. During the application of water to the lysimeters which contained various combinations and soil, the lysimeter leachate was monitored to determine the effect of the spent filter sand on leachate quality. Figures 31 to 40 in Appendix B show the relationship between the parameters monitored and the amount of water applied to each lysimeter. Each parameter is discussed below.

Ammonia. The effect the spent filter sand had on the leachate ammonia-nitrogen concentration is shown in Figures 31 and 32 in Appendix B. In general, the leachate from all four soils increased in ammonia-nitrogen and remained high in ammonia-nitrogen throughout the entire study. The Parley soil had the greatest increase in leachate ammonia-nitrogen concentrations. However, after reaching a peak concentration of approximately 3.5 mg/l NH_3-N the leachate ammonia-nitrogen concentration from the Parley soil decreased rapidly.

In general, the leachate from the soils which had an addition of spent filter sand had a slightly higher ammonia-nitrogen concentration than leachate from the control lysimeters without spent filter sand added. However, in all cases, except for the Parley soil, this increase was not significant.

Nitrite. The effect of spent filter sand on the leachate nitrite-nitrogen concentration is shown in Figures 33 and 34 in Appendix B. In general, all soil types had leachate nitrite-nitrogen concentrations higher in these soils that had applied spent filter sand. Only the Parley soil showed an increase in NO_2-N after initial water irrigation. The higher NO_2-N concentrations in the spent filter sand containing lysimeters can only be attributed to the presence of the algae laden sand. The very low NO_2-N concentrations were used as a reason for terminating analysis for NO_2-N in the samples after 30 cm of applied water.

Nitrate. The effect of addition of spent filter sand on leachate nitrate-nitrogen concentrations from the four soils is shown in Figures 35 and 36 in Appendix B. In general, the leachate from the soils with spent filter sand additions had a greater nitrate-nitrogen concentration than did the soils without the addition of spent filter sand. In addition, the leachate nitrate-nitrogen concentrations decreased with application of water.

For the two silty loam soils (Parley and Nibley) it appears that the leachate from the spent filter sand covered soil may have had slightly more nitrate-nitrogen than leachate from the other soils. Leachate from the Clay soil showed no appreciable difference throughout eight weeks of irrigation. The sandy loam soil (Draper) leachate also did not show any significant difference. The high initial leachate nitrate-nitrogen concentrations from the Nibley loam is proably due to a washing out and oxidation of fertilizer which was applied to the soil prior to collection of the soil sample.

In general, leachate nitrate-nitrogen concentrations are very high indicating that these soils are capable of producing a highly oxidized leachate.

Orthophosphorus and total phosphorus. The affect of addition of spent filter sand on the leachate orthophosphorus concentration from each of the four soils is shown in Figures 37 and 38 in Appendix B. In general, the addition of the spent filter sand increased the leachate orthophosphorus concentrations for three of the four soil types. However, this increase was in most cases less than 0.1 mg/l. The addition of the spent filter sand had the greatest affect on leachate orthophosphorus concentrations from the Clay soil. In the Clay, the leachate orthophosphorus concentration was greater than the control leachate concentrations throughout the entire study.

The Nibley soil leachate orthophosphorus concentration did not follow the response of the three other soils. The leachate orthophosphorus concentration from the Nibley soil with spent filter sand was less than that from the Nibley soil without spent filter sand. This suggests that the Nibley soil had a high phosphorus content before it was selected for use in the study.

Leachate total phosphorus concentrations are shown in Figures 39 and 40 in Appendix B. In general, the response of the leachate total phosphorus concentration was similar to that for orthophosphorus as discussed.

Summary

The results of this phase of study do not clearly indicate the affect that addition of spent filter sand will have on the physical and chemical properties of Parley, Nibley, Draper or Clay soils. Further study and additional sampling is required to clearly delineate these affects. The results do indicate, however, that the leachate from soils which have additions of spent filter sand are slightly higher in certain nutrients (NH_3-N, NO_3-N, phosphorus). Although, in general, these increases in leachate nutrient levels are small, the results do substantiate the findings of Phase I: Sand Rejuvenation.

Data from Phase I: "Sand Rejuventation" indicated that nutrients were released from the spent filter sand at a decreasing rate. Analysis of the leachate from soil containing additions of spent filter sand indicate the release of nutrients from the spent filter sand. However, the increase in leachate nutrient concentrations was greater in Phase I than in Phase II.

From the limited amount of data collected in Phase II it is difficult to determine which soil type benefited the most from addition of the spent filter sand. However, in general, the Parley soil and the Clay soil seemed to show a greater increase in nutrient levels than did the Nibley or Draper soils.

Phase III: Plant Bioassay

Phase III: "Plant Bioassay" was designed to determine the feasibility of using the spent filter sand as a soil amendment and fertilizer. The experiment compared the growth or yield of a grass (tall fescue) grown in (i) a clay soil without addition of spent filter sand, (ii) a clay soil with the addition of spent filter sand sufficient to provide 56 kg/ha (50 lbs/ac) nitrogen, (iii) a clay soil with the addition of spent filter sand to provide 112 kg/ha (100 lbs/ac) nitrogen and (iv) a clay soil without spent filter sand but with the addition of a commercial fertilizer at the rate of 112 kg/ha (100 lbs/ac) nitrogen. The soil mixtures were placed in lysimeters and seeded on two different occasions as discussed in the Procedure Chapter. After five weeks a grass clipping sample was taken and the dry weight of the grass determined. A second dry weight clipping analysis was taken two weeks later.

Grass yield

The yield or productivity of the tall fescue grass grown on the lysimeters for each of the two sample dates is shown in Figure 30. The values in Figure 30 are an average of at least two separate analyses. A complete list of the data is in Table 13.

A statistical analysis of the data in using a student "t" test indicated that at 95 percent confidence the mean values of dry weight from all of the lysimeters were not shown to be from different populations. Thus, there was no statistically significant difference in the yield of the grass from any of the treatments. However, this lack of statistical significance is probably due to the small number of samples collected.

A numerical comparison of the dry weights determined on May 2, 1976, indicated that all of the treated lysimeters (i.e., commercial fertilizer and spent filter sand) had mean values that were at least 58.4 percent greater than the control value (clay soil alone). The mean dry weight for the control lysimeters was 0.7861 grams (0.0253 ounces) while the clay soil with 112 kg/ha (100 lbs/ac) nitrogen as commercial fertilizer mean dry weight was 1.2448 grams (0.04 ounces), the clay soil with 56 kg/ha (50 lbs/ac) nitrogen as spent filter sand mean dry was 1.5575 grams (0.050 ounces) and the clay soil with 100 kg/ha (100 lbs/ac) nitrogen as spent filter sand was 1.8093 (0.058 ounces). This indicates an increase in grass yield with addition of the spent filter sand greater than that achieved with commercial fertilizer.

A statistical analysis of the data from May 16, 1976, utilizing the same student "t" test indicated that all the mean dry weight could not be shown to have come from different populations except in comparing (i) the clay soil without additions to the clay soil with commerical fertilizer and (ii) the clay soil with 56 kg/ha (50 lbs/ac) nitrogen as spent filter

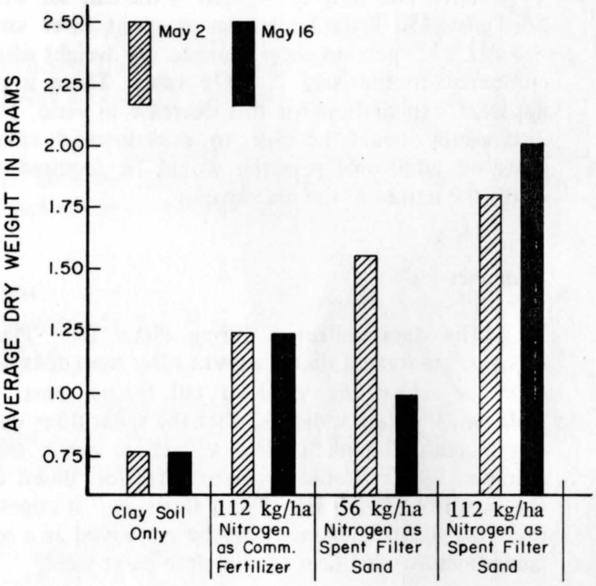

Figure 30. Mean dry weights of clippings from lysimeters.

Table 13. Dry weight of tall fescue grass collected during Phase III: Plant Bioassay.

Sample Description	Sample Number	Dry Weight in Grams	
		May 2, 1976	May 16, 1976
Clay Soil	A	1.0907	0.7951
	B	0.4814	0.7377
	Average	0.7861	0.7664
Clay Soil with 18.4 kg/ha Nitrogen as Commercial Fertilizer	A	1.4076	1.1348
	B	1.0819	1.3420
	Average	1.2448	1.2384
Clay Soil with 9.2 kg/ha Nitrogen as Spent Filter Sand	A	1.4066	0.8589
	B	1.8655	1.2537
	C	1.4004	0.8093
	Average	1.5575	0.9740
Clay Soil with 18.4 kg/ha Nitrogen as Spent Filter Sand	A	1.1614	2.0040
	B	2.1469	2.6866
	C	2.1197	1.4534
	Average	1.8093	2.0480

sand to the clay soil with 112 kg/ha (100 lbs/ac) nitrogen as spent filter sand. This is probably due to the additional nitrogen application in each case. The lack of statistical significance at the 95 percent level in the other cases is probably due to the small number of samples.

Although the dry weight means in general are not statistically different on May 16, 1976, they do appear to present the same numerical trend as revealed on May 2, 1976. However, there is one exception in the numerical analysis of the May 16, 1976, data. The mean dry weight of the clay soil with 56 kg/ha (50 lbs/ac) nitrogen as spent filter sand shows a 37.5 percent drop in mean dry weight when compared to the May 2, 1976 value. There is no apparent explanation for this decrease in yield. The discrepancy could be due to experimental error; however, additional research would be required to verify the nature of the discrepancy.

Summary

The data collected during Phase III: "Plant Bioassay" indicated that the spent filter sand does not deter or retard the yield of tall fescue grass. In addition, the data indicated that the spent filter sand can increase the plant yield as well or better than commerically available nitrogen fertilizer. Based on the results of Phase III: "Plant Bioassay," it appears that the spent filter sand may be employed as a soil amendment or fertilizer to stimulate plant yield.

Cost Estimate

General

A rough cost estimate for each of the three disposal alternatives evaluated in this study is presented below. Estimated costs for the (i) irrigation technique of spent filter sand rejuvenation, (ii) use of the spent filter sand as a soil conditioner and (iii) use of the spent filter sand as a plant stimulant or fertilizer were based on current costs (May 1976) obtained from consulting engineers and equipment suppliers. A complete breakdown of each cost estimate is recorded in Appendix C.

Irrigation technique

If 170 cm of washing water is applied to the spent filter sand at 5 cm a day, about 7 weeks would be needed to rejuvenate the sand. Careful filter operation could provide for filter plugging to occur about every 7 weeks, however, adverse lagoon conditions could cause more frequent plugging and storage would have to be provided.

Based on the above assumption a 0.34 hectare (0.835 acre) intermittent sand filter would produce about 47.4 cubic meters (63 cu yds) of spent filter sand per plugging. Application of spent filter sand approximately 20 cm (7.9 in.) deep would require a washing area of 237 square meters (283 sq. yds). At $5 per cubic meter for excavation, $1,150 would be required for excavation of the sand washing area, $1,130 would be sufficient for laying concrete in the basin. Piping would have to provide 11.9 m^3 of water (3,145 gallons) to irrigate the spent filter sand every day. Total head required for the irrigation technique would depend on proximity of the washing facilities to the intermittent sand filters.

The intermittent sand filters may plug from zero to seven times per year. A reasonable average would be four pluggings or less per year. Each plugging would involve a small grader and shovel which would rent for about $20.00/hr with operator. Total cost for one day of filter scraping of 2 cm (0.8 in.) of sand would be $160/day or $640 per year.

One pump would be necessary for the washing operation (a standby pump would not be necessary). Total cost of a pump, panel, and pump house to deliver 0.085 m^3/min (22.5 gallons/min) through 150 meters (500 ft) of pipe with 7.6 meters (25 feet) of head would be $2500. Total pipe cost for the installation would be approximately $760.

Thus, the total capital cost for the irrigation technique would be approximately $5890. Annual operation and maintenance costs would be approximately $640. Using an amortization rate of 7 percent, the total annual cost of the irrigation system would be approximately $1115 per year. Table 41 in Appendix C tabulates these figures.

Soil conditioner or fertilizer

In addition, $640 per year would also be needed for removal of sand when disposed of on land. Truck and operator cost for a 40 mile round trip to disposal site would be about $705 per year. Replacement sand for the scraped filter would cost $950/year. Total cost would be $2295 almost double the cost of irrigation. However, if a market could be developed for the sand scrapings to such an extent that buyers would remove the scraped sand from the treatment area, cost could be reduced to near $1600 per year. Table 42 in Appendix C summarizes the soil conditioner cost.

Deposition of filter scrapings in a sanitary landfill would cost more than irrigation or land application as landfill space would have to be purchased in addition to scraping and hauling costs. Cost for disposal would range between 61 cents per 1000 gallons and $1.26 per 1000 gallons.

CHAPTER V

SUMMARY AND CONCLUSIONS

The use of intermittent sand filters has been shown to be an acceptable method for upgrading wastewater lagoon effluents. However, the rejuvenation or disposal of the spent filter sand from the intermittent sand filtration process is one of the major disadvantages of the system.

This report presents the results of a twelve month laboratory scale study to determine the feasiblity of three possible low cost alternatives for rejuvenation or disposal of spent filter sand. The study was divided into three phases. Phase I: "Sand Rejuvenation" investigated the feasibility of a new irrigation technique for rejuvenation of spent filter sand. The results of Phase I indicated that the irrigation technique is capable of rejuvenating the spent filter sand for minimum cost.

Phase II: "Soil Conditioner" assessed the feasibility of using the spent filter sand as a soil conditioner. An attempt was made to determine the affect of spent filter sand on the leachate, physical and chemical properties of Parley, Nibley, Clay and Draper soils. In general, the results of Phase II were inconclusive.

Phase III: "Plant Bioassay" investigated the affect of spent filter sand mixed with a clay soil on the yield of tall fescue grass and compared that yield to the yield produced by commercial fertilizer. Although statistical significance could not be shown, a numerical analysis indicated that spent filter sand stimulated yield more than the commercial fertilizer.

Based on the results of the study the following conclusions can be made.

1. Effluent from the irrigation technique would reach acceptable BOD_5 concentrations after the application of 55 cm (21.7 in.) of water.

2. In terms of BOD_5 of the irrigation technique effluent, a spent filter sand depth of 21 cm (8.3 in.) appears to be better than a 12 cm (4.7 in.) or a 46 cm (18.1 in.) depth.

3. To produce an effluent suspended solids concentration of 5.0 mg/l from the irrigation technique a 12 cm (4.7 in.) depth of sand is required.

4. A 21 cm (8.3 in.) depth of spent filter sand is desirable for efficient volatile suspended solids leachate performance by the irrigation technique.

5. It appears that 70 cm (27.6 in.) of applied water is required to produce acceptable ammonia-nitrogen levels in leachate from the irrigation technique.

6. Deeper depths of spent filter sand are desirable for low irrigation technique leachate nitrate-nitrogen concentrations.

7. The amount of orthophosphorus in the irrigation technique may limit or prevent the direct discharge of leachate to a receiving stream.

8. Leachate from the irrigation technique is acceptable for use as an irrigation water.

9. Experiments to determine the effect of spent filter sand on the physical and chemical properties of Parley, Nibley, Clay and Draper soils were inconclusive. Additional research is required.

10. Spent filter sand stimulates the yield of tall fescue grass as much or more than an equal amount of commercial fertilizer.

11. Natural exposure of spent filter sand to conditions in northwestern Utah does not sufficiently rejuvenate the sand for continued use on the filters within an acceptable time span.

12. Cost of disposal of sand scrapings increases the total cost of a filter operation by about 35 percent.

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APPENDIXES

Appendix A

Tabulated Data from Phase I

Table 14. Phase I data summary after 0 cm (0 inch) of applied water.

Sample Date: 7/25/75
Days since beginning application: 0

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD_5 mg/l	o-PO_4-P mg/l	Na meq/l	Hard-ness meq/l	EC µmhos/cm	SAR	Soil[a] Type	NO_2-N mg/l	NO_3-N mg/l	NH_3-N mg/l
1A	46-C	1.4	0.5	2.46	4.9	0.000	0.252	2.56	268	0.223	C2-S1	0.012	0.270	0.067
1B	46-SC	50.3	42.5	2.19	>270	4.00	3.04	19.5	3,607	0.971	C4-S1	57.9	229	105
2A	21-C	11.4	1.2	2.00	4.2	0.000	0.152	2.82	295	0.128	C2-S1	0.013	0.349	0.032
2B	21-SC	65.9	48.2	3.46	93.4	3.27	1.39	10.3	1,492	0.612	C3-S1	72.9	44.6	68.4
3A	12-C	12.0	1.0	2.24	2.6	0.000	0.144	3.20	314	0.114	C2-S1	0.006	0.381	0.030
3B	12-SC	78.7	36.9	2.66	79.2	2.77	1.22	7.80	1,581	0.619	C2-S1	49.0	60.9	81.2

[a] See Figure 27.

Table 15. Phase I data summary after 5 cm (1.97 inches) of applied water.

Sample Date: 7/29/75
Days since beginning application: 5

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD_5 mg/l	o-PO_4-P mg/l	Na meq/l	Hard-ness meq/l	EC µmhos/cm	SAR	Soil[a] Type	NO_2-N mg/l	NO_3-N mg/l	NH_3-N mg/l
1A	46-C	1.9	0.82	0.45	> 6.8	0.006	0.204	2.92	286	0.169	C2-S1	0.006	0.289	0.027
1B	46-SC	71.1	68.2	1.16	>288	9.116	2.35	18.2	2,470	0.781	C4-S1	46.5	192	188
2A	21-C	27.6	2.7	0.54	6.4	0.054	0.122	2.63	278	0.106	C2-S1	0.018	0.441	0.039
2B	21-SC	33.6	34.0	0.94	80.2	5.53	1.26	6.14	1,828	0.720	C3-S1	18.3	84.9	60.1
3A	12-C	11.7	1.43	0.58	4.9	0.023	N.A.	3.27	316	N.A.	N.A.	0.003	0.297	0.078
3B	12-SC	14.9	11.2	0.94	46.8	2.729	0.565	3.42	751	0.431	C3-S1	2.3	12.2	34.8

[a] See Figure 27.
N.A. – Data not available.

Table 16. Phase I data summary after 15 cm (5.9 inches) of applied water.

Sample Date: 7/31/75
Days since beginning application: 7

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD_5 mg/l	o-PO_4-P mg/l	Na meq/l	Hard-ness meq/l	EC µmhos/cm	SAR	Soil[a] Type	NO_2-N mg/l	NO_3-N mg/l	NH_3-N mg/l
1A	46-C	4.0	1.1	0.45	2.4	0.007	0.091	2.30	192	0.087	C1-S1	0.006	0.582	0.020
1B	46-SC	71.2	61.0	0.62	82	24.5	1.22	11.6	1,847	0.975	C3-S1	16.1	82.8	113
2A	21-C	5.5	1.2	0.30	1.6	0.13	0.0783	2.9	230	0.065	C1-S1	0.007	0.564	0.020
2B	21-SC	11.5	12.8	0.60	26	17.1	0.374	5.02	595	0.237	C2-S1	1.32	8.03	44.1
3A	12-C	3.1	0.8	0.17	2.0	0.027	0.087	2.85	237	0.073	C1-S1	0.004	0.519	0.028
3B	12-SC	6.5	6.5	0.49	9.4	8.23	0.226	3.54	369	0.200	C2-S1	0.178	1.88	40.5

[a] See Figure 27.

Table 17. Phase I data summary after 30 cm (11.8 inches) of applied water.

Sample Date: 8/5/75
Days since beginning application: 12

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hardness meq/l	EC μmhos/cm	SAR	Soil[a] Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	2.9	0.5	0.71	2.2	0.016	0.217	2.46	265	0.195	C2-S1	0.006	0.247	0.044
1B	46-SC	34.0	21.8	0.32	71.4	9.08	0.913	8.80	1,413	0.435	C3-S1	2.1	0.989	55.1
2A	21-C	3.6	0.34	0.61	1.4	0.029	0.235	3.23	332	0.185	C2-S1	0.011	0.323	0.090
2B	21-SC	5.8	4.7	0.87	5.3	7.63	0.383	5.29	720	0.235	C2-S1	3.2	10.3	17.6
3A	12-C	117	7.9	0.54	2.2	0.015	0.248	3.45	336	0.188	C2-S1	0.014	0.290	0.054
3B	12-SC	4.5	3.4	0.92	2.4	3.56	0.400	4.16	487	0.278	C2-S1	0.53	0.937	9.06

[a]See Figure 27.

Table 18. Phase I data summary after 40 cm (15.7 inches) of applied water.

Sample Date: 8/7/75
Days since beginning application: 14

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hardness meq/l	EC μmhos/cm	SAR	Soil[a] Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	N.A.	1.61	N.A.	2.3	0.027	0.200	2.45	N.A.	0.182	C2-S1	0.007	0.251	0.315
1B	46-SC	N.A.	20.9	N.A.	62.8	8.58	0.783	8.06	1,070	0.390	C3-S1	0.049	0.121	62.2
2A	21-C	N.A.	2.31	N.A.	1.3	0.015	0.652	3.19	306	0.517	C2-S1	0.003	0.263	0.055
2B	21-SC	N.A.	0.89	N.A.	3.5	6.46	0.826	5.06	548	0.519	C2-S1	1.30	5.91	14.8
3A	12-C	N.A.	1.85	N.A.	1.1	0.013	0.226	2.99	322	0.185	C2-S1	0.006	0.248	0.043
3B	12-SC	N.A.	1.78	N.A.	1.5	3.37	0.244	4.19	421	0.168	C2-S1	1.16	0.881	28.1

[a]See Figure 27.
N.A. – Data not available.

Table 19. Phase I data summary after 55 cm (21.7 inches) of applied water.

Sample Date: 8/12/75
Days since beginning application: 19

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hardness meq/l	EC μmhos/cm	SAR	Soil[a] Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	4.50	1.02	0.40	1.96	0.085	0.109	2.55	260	0.096	C2-S1	0.005	0.218	0.249
1B	46-SC	7.06	6.23	0.67	67.0	9.46	0.348	8.13	1,040	0.172	C3-S1	0.203	0.755	43.0
2A	21-C	3.73	0.88	0.53	0.86	0.005	0.109	3.09	310	0.089	C2-S1	0.004	0.234	0.029
2B	21-SC	3.24	3.35	0.73	5.6	5.69	0.217	5.20	541	0.135	C2-S1	2.189	6.91	3.26
3A	12-C	3.52	0.90	0.24	0.87	0.007	0.204	3.08	320	0.165	C2-S1	0.007	0.236	0.031
3B	12-SC	4.00	3.19	0.35	4.48	2.43	0.213	4.23	408	0.146	C2-S1	2.768	1.36	3.01

[a]See Figure 27.

Table 20. Phase I data summary after 70 cm (27.6 inches) of applied water.

Sample Date: 8/15/75
Days since beginning application: 22

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hardness meq/l	EC μmhos/cm	SAR	Soil[a] Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	3.01	0.38	0.44	0.86	0.014	0.043	2.61	250	0.030	C2-S1	0.004	0.273	0.066
1B	46-SC	7.29	5.41	0.65	39.3	9.88	0.348	6.58	816	0.192	C3-S1	0.030	0.213	30.38
2A	21-C	3.57	0.45	0.24	0.53	0.006	0.087	3.13	286	0.070	C2-S1	0.001	0.248	0.030
2B	21-SC	2.28	1.50	0.72	3.84	4.95	0.204	4.60	461	0.161	C2-S1	0.791	3.47	4.00
3A	12-C	6.10	0.55	0.56	0.64	0.010	0.109	3.30	321	0.085	C2-S1	0.006	0.324	0.037
3B	12-SC	3.74	1.68	0.71	2.10	2.60	0.204	4.15	401	0.142	C2-S1	1.387	3.09	1.11

[a]See Figure 27.

Table 21. Phase I data summary after 85 cm (33.5 inches) of applied water.

Sample Date: 8/20/75
Days since beginning application: 27

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hard-ness meq/l	EC μmhos/cm	SAR	Soil[a] Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	2.67	0.38	N.A.	0.93	0.012	0.043	2.51	214	0.038	C1-S1	0.002	0.205	0.031
1B	46-SC	8.82	5.24	0.70	35.9	7.63	0.348	6.38	633	0.194	C2-S1	0.168	1.36	22.1
2A	21-C	3.11	0.43	0.54	0.59	0.008	0.087	3.22	272	0.069	C2-S1	0.001	0.212	0.040
2B	21-SC	2.71	2.02	0.46	3.97	4.15	0.183	4.70	401	0.120	C2-S1	0.537	3.39	2.20
3A	12-C	4.99	0.48	0.56	0.66	0.009	0.087	3.09	280	0.070	C2-S1	0.002	0.227	0.037
3B	12-SC	2.06	1.17	0.51	1.61	2.18	0.191	4.21	342	0.132	C2-S1	0.664	2.40	0.300

[a] See Figure 27.
N.A. – Data not available.

Table 22. Phase I data summary after 100 cm (39.4 inches) of applied water.

Sample Date: 8/25/75
Days since beginning application: 32

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hard-ness meq/l	EC μmhos/cm	SAR	Soil[a] Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	3.39	0.52	0.29	0.65	0.005	0.087	2.70	241	0.075	C1-S1	0.003	0.243	0.032
1B	46-SC	15.6	9.24	0.57	30.8	6.07	0.348	6.98	715	0.186	C2-S1	0.582	3.418	21.3
2A	21-C	4.32	0.64	0.39	0.38	0.003	0.043	3.11	252	0.035	C2-S1	0.002	0.214	0.162
2B	21-SC	1.83	1.37	0.60	2.04	3.83	0.230	4.83	419	0.147	C2-S1	0.728	7.91	1.37
3A	12-C	11.2	1.05	0.49	0.38	0.002	0.565	3.06	275	0.456	C2-S1	0.002	0.250	0.028
3B	12-SC	2.06	1.14	0.33	1.19	2.32	0.183	4.00	323	0.130	C2-S1	0.055	2.97	1.51

[a] See Figure 27.
Comments: 2A – possible dirty bucket (NH_3-N). Core sample from front of basins.

Table 23. Phase I data summary after 115 cm (42.3 inches) of applied water.

Sample Date: 8/28/75
Days since beginning application: 35

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hard-ness meq/l	EC μmhos/cm	SAR	Soil[a] Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	3.46	0.44	0.27	0.80	0.004	0.043	3.09	246	0.035	C1-S1	0.001	0.200	0.036
1B	46-SC	9.01	6.32	0.64	15.0	3.19	0.174	5.75	625	0.102	C2-S1	0.347	2.19	19.4
2A	21-C	2.23	0.42	0.18	0.50	0.004	0.043	3.22	286	0.034	C2-S1	0.001	0.201	0.020
2B	21-SC	1.82	1.12	0.62	1.54	1.80	0.050	4.54	394	0.033	C2-S1	0.127	2.40	1.31
3A	12-C	4.19	0.61	0.32	0.57	0.003	0.086	3.30	296	0.067	C2-S1	0.002	0.206	0.020
3B	12-SC	1.18	0.83	0.47	0.92	1.03	0.050	4.16	354	0.035	C2-S1	0.021	1.25	0.795

[a] See Figure 27.
Comments: Core samples from west end of boxes.

Table 24. Phase I data summary after 130 cm (51.2 inches) of applied water.

Sample Date: 9/2/75
Days since beginning application: 40

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hard-ness meq/l	EC μmhos/cm	SAR	Soil[a] Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	1.73	0.42	0.54	0.56	0.005	0.050	2.57	239	0.044	C1-S1	0.001	0.238	0.008
1B	46-SC	9.20	5.71	0.64	11.3	5.21	0.261	5.72	559	0.154	C2-S1	0.389	4.91	12.2
2A	21-C	1.62	0.80	0.48	0.19	0.005	0.130	3.24	288	0.101	C2-S1	0.001	0.173	0.006
2B	21-SC	1.79	1.21	0.71	1.68	2.20	0.050	4.56	409	0.033	C2-S1	0.204	3.51	0.425
3A	12-C	2.01	0.42	0.23	0.46	0.005	0.043	3.39	305	0.033	C2-S1	0.001	0.211	0.008
3B	12-SC	0.77	0.65	0.42	0.83	1.49	0.043	4.06	359	0.030	C2-S1	0.093	1.51	0.022
Influent							0.035	3.47	315	0.026	C2-S1			

[a] See Figure 27.

Table 25. Phase I data summary after 145 cm (57.1 inches) of applied water.

Sample Date: 9/5/75
Days since beginning application: 43

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hard-ness meq/l	EC µmhos/cm	SAR	Soil Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A	46-C	3.53	0.46	0.40	0.29	0.010						0.001	0.205	0.007
1B	46-SC	5.95	3.34	0.36	7.0	4.594						0.191	1.75	15.5
2A	21-C	2.65	0.41	0.49	0.57	0.013						0.001	0.234	0.006
2B	21-SC	2.98	2.77	0.68	1.15	2.538						0.023	1.95	0.626
3A	12-C	2.95	0.40	0.50	0.57	0.010						0.001	0.251	0.014
3B	12-SC	0.77	0.56	0.53	1.31	1.462						0.002	1.116	0.017

Comments: Na, hardness, EC, SAR, and soil type discontinued levels were not sufficiently greater than influent water to warrant continued monitoring. (See Table 24.)

Table 26. Phase I data summary after 160 cm (63.0 inches) of applied water.

Sample Date: 9/10/75
Days since beginning application: 48

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hard-ness meq/l	EC µmhos/cm	SAR	Soil Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A		2.42	0.94	0.20	0.6	0.002						0.001	0.346	0.011
1B		5.70	4.14	0.58	6.6	3.89						0.220	4.13	12.8
2A		2.06	0.89	0.32	0.5	0.003						0.000	0.395	0.023
2B		11.2	3.82	0.49	1.6	1.98						0.018	3.04	0.460
3A		3.32	0.92	0.20	0.5	0.002						0.000	0.289	0.088
3B		0.55	1.08	0.48	0.9	1.18						0.003	1.45	0.027

Comments: Na, hardness, EC, SAR, and soil type discontinued. Levels were not sufficiently greater than influent water to warrant continued monitoring. (See Table 24.)

Table 27. Phase I data summary after 190 cm (74.8 inches) of applied water.

Sample Date: 9/18/75
Days since beginning application: 54

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD$_5$ mg/l	o-PO$_4$-P mg/l	Na meq/l	Hard-ness meq/l	EC µmhos/cm	SAR	Soil Type	NO$_2$-N mg/l	NO$_3$-N mg/l	NH$_3$-N mg/l
1A		2.85	0.67	0.41	0.1	0.006						0.001	0.229	0.006
1B		4.30	2.45	0.38	3.5	3.21						0.099	1.52	7.16
2A		2.26	0.47	0.20	0.7	0.000						0.001	0.209	0.008
2B		1.68	0.94	0.58	0.5	1.63						0.008	2.09	0.238
3A		4.96	0.65	0.50	0.4	0.009						0.002	0.177	0.003
3B		2.90	0.93	0.57	0.5	0.770						0.001	0.550	0.015

Comments: Na, hardness, EC, SAR, and soil type discontinued. Levels were not sufficiently greater than influent water to warrant continued monitoring. (See Table 24.)

Table 28. Phase I data summary after 220 cm (86.6 inches) of applied water.

Sample Date: 9/26/75
Days since beginning application: 62

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD_5 mg/l	o-PO_4-P mg/l	Na meq/l	Hard-ness meq/l	EC μmhos/cm	SAR	Soil Type	NO_2-N mg/l	NO_3-N mg/l	NH_3-N mg/l
1A	46-C	2.17	0.72	0.36	0	0.008						0.000	0.210	0.017
1B	46-SC	2.70	1.94	0.57	2.5	2.97						0.066	1.26	3.41
2A	21-C	3.11	0.73	0.18	0.6	0.008						0.000	0.223	0.013
2B	21-SC	1.10	0.95	0.40	0.6	1.60						0.006	1.68	0.090
3A	12-C	3.55	0.74	0.32	0.3	0.013						0.001	0.217	0.005
3B	12-SC	0.70	0.82	0.45	0.4	0.860						0.000	0.669	0.020

Comments: Na, hardness, EC, SAR, and soil type discontinued. Levels were not sufficiently greater than influent water to warrant continued monitoring. (See Table 24.)

Table 29. Phase I data summary after 245 cm (96.5 inches) of applied water.

Sample Date: 10/3/75
Days since beginning application: 69

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD_5 mg/l	o-PO_4-P mg/l	Na meq/l	Hard-ness meq/l	EC μmhos/cm	SAR	Soil Type	NO_2-N mg/l	NO_3-N mg/l	NH_3-N mg/l
1A		2.65	0.71		0.84	0.00							0.199	0.010
1B		2.91	1.41		3.0	2.88						0.056	1.32	6.09
2A		1.88	0.23		0.7	0.022							0.228	0.013
2B		0.79	0.46		1.0	1.73							1.84	0.198
3A		2.88	0.30		1.0	0.014							0.021	0.010
3B		0.82	0.43		1.1	0.927							0.094	0.031

Comments: Terminated application of water to 3A and 3B. NO_2-N (assume 0 on all other values). $\therefore NO_3 + NO_2 = NO_3$
Na, hardness, EC, SAR, and soil type discontinued. Levels were not sufficiently greater than influent water to warrant continued monitoring. (See Table 24.)

Table 30. Phase I data summary after 270 cm (106 inches) of applied water.

Sample Date: 10/10/75
Days since beginning application: 76

Sample	Depth C or SC	SS mg/l	VSS mg/l	VS % Dry Core	BOD_5 mg/l	o-PO_4-P mg/l	Na meq/l	Hard-ness meq/l	EC μmhos/cm	SAR	Soil Type	NO_2-N mg/l	NO_3-N mg/l	NH_3-N mg/l
1A	46-C	2.57	0.00		0.2	0.006							0.185	0.020
1B	46-SC	2.52	0.08		4.8	2.21							1.10	4.47
2A	21-C	1.88	0.03		0.2	0.013							0.212	0.023
2B	21-SC	1.46	0.1		0.9	1.33							1.15	0.173
3A	12-C													
3B	12-SC													

Comments: Na, hardness, EC, SAR, and soil type discontinued. Levels were not sufficiently greater than influent water to warrant continued monitoring. (See Table 24.)

Appendix B

Tabulated Data from Phase II

Table 31. Summary of symbols used in tables of Appendix B.

Symbol	Meaning
CT	Sample from 8.9 cm (3.5 in.) depth of clay soil with applied spent filter sand
CB	Sample from 53 cm (20.9 in.) depth of clay soil with applied spent filter sand
CCT	Sample from 8.9 cm (3.5 in.) depth of clay soil without sand application
CCB	Sample from 53 cm (20.9 in.) depth of clay soil without sand application
DT	Sample from 8.9 cm (3.5 in.) depth of Draper soil with applied spent filter sand
DB	Sample from 53 cm (20.9 in.) depth of Draper soil with applied spent filter sand
DCT	Sample from 8.9 cm (3.5 in.) depth of Draper soil without sand application
DCB	Sample from 53 cm (20.9 in.) depth of Draper soil without sand application
PT	Sample from 8.9 cm (3.5 in.) depth of Parley soil with applied spent filter sand
PB	Sample from 53 cm (20.9 in.) depth of Parley soil with applied spent filter sand
PCT	Sample from 8.9 cm (3.5 in.) depth of Parley soil without sand application
PCB	Sample from 53 cm (20.9 in.) depth of Parley soil without sand application
NT	Sample from 8.9 cm (3.5 in.) depth of Nibley soil with applied spent filter sand
NB	Sample from 53 cm (20.9 in.) depth of Nibley soil with applied spent filter sand
NCT	Sample from 8.9 cm (3.5 in.) depth of Nibley soil without sand application
NCB	Sample from 53 cm (20.9 in.) depth of Nibley soil without sand application
N.A.	Data not available
I.S.	Insufficient sample to obtain analysis
Overflow	Effluent volume exceeded volume of capture container

Table 32. Phase II data summary after 5.08 cm (2 inches) of applied water.

Sample Date: 10/29/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	O-PO_4 mg/l	Total P mg/l	Liters Effluent
CT	N.A.	11.5	0.027	0.251	0.403	N.A.
CB	N.A.	18.5	0.019	0.221	0.357	N.A.
CCT	N.A.	4.97	0.017	0.137	0.914	N.A.
CCB	N.A.	16.2	0.010	0.137	1.19	N.A.
DT	N.A.	18.4	0.033	0.190	0.899	N.A.
DB	N.A.	74.7	0.072	0.319	0.481	N.A.
DCT	N.A.	25.6	0.006	0.144	0.589	N.A.
DCB	N.A.	65.2	0.009	0.357	0.620	N.A.
NT	N.A.	66.8	0.037	0.470	I.S.	N.A.
NB	N.A.	769.	0.011	0.038	I.S.	N.A.
NCB	N.A.	1240	0.029	0.221	0.512	N.A.
NCT	N.A.	73.2	0.005	0.342	19.0	N.A.
PT	N.A.	46.6	0.074	0.540	8.81	N.A.
PB	N.A.	79.5	0.011	0.798	0.930	N.A.
PCT	N.A.	53.4	0.011	0.586	1.10	N.A.
PCB	N.A.	71.4	0.007	0.669	0.977	N.A.

Table 33. Phase II data summary after 7.62 cm (3 inches) of applied water.

Sample Date: 11/4/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	O-PO_4 mg/l	Total P mg/l	Liters Effluent
CT	0.105	15.2	0.122	0.231	I.S.	0.460
CB	0.048	18.7	0.003	0.563	0.635	2.64
CCT	I.S.	16.6	0.047	0.138	I.S.	0.230
CCB	0.150	21.4	0.003	0.147	0.036	3.57
DT	0.143	21.0	0.201	I.S.	I.S.	0.135
DB	0.108	88.1	0.033	0.422	0.749	4.10
DCT	0.046	27.6	0.012	0.219	I.S.	0.190
DCB	0.130	67.3	0.015	0.356	0.472	4.46
NT	0.071	39.4	0.050	0.556	1.35	N.A.
NB	0.074	565	0.017	0.273	0.374	3.97
NCB	0.051	900	0.019	0.119	0.456	4.05
NCT	I.S.	I.S.	0.025	I.S.	I.S.	0.10
PT	I.S.	I.S.	I.S.	I.S.	I.S.	0.005
PB	0.247	76.6	0.048	0.773	1.03	4.11
PCT	I.S.	I.S.	I.S.	I.S.	I.S.	0.045
PCB	0.052	58.8	0.009	0.669	0.993	2.23

Table 34. Phase II data summary after 10.2 cm (4 inches) of applied water.

Sample Date: 11/11/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	O-PO_4 mg/l	Total P mg/l	Liters Effluent
CT	0.068	11.6	0.262	0.274	0.310	0.560
CB	0.064	19.8	0.019	0.239	0.356	2.66
CCT	I.S.	9.61	I.S.	0.163	0.287	0.05
CCB	0.042	23.9	0.004	0.142	0.189	3.73
DT	0.118	14.1	0.424	0.355	0.493	0.17
DB	0.091	67.5	0.018	0.279	0.356	4.61
DCT	I.S.	16.4	I.S.	0.186	0.218	0.11
DCB	0.101	59.8	0.013	0.321	0.407	4.47
NT	0.094	14.2	0.212	0.561	0.789	0.470
NB	0.064	363	0.010	0.298	0.373	3.40
NCB	0.037	452	0.014	0.312	0.396	3.73
NCT	0.091	I.S.	0.007	0.244	0.294	0.140
PT	I.S.	I.S.	I.S.	I.S.	I.S.	0.0
PB	0.337	64.8	0.053	0.884	N.A.	4.68
PCT	0.052	25.5	I.S.	0.528	0.596	0.10
PCB	0.069	42.4	0.007	0.699	0.734	2.01

Table 35. Phase II data summary after 15.2 cm (6 inches) of applied water.

Sample Date: 11/18/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	O-PO_4 mg/l	Total P mg/l	Liters Effluent
CT	0.086	14.7	0.498	0.340	1.69	0.745
CB	0.067	20.5	0.044	0.267	0.868	1.690
CCT	0.084	9.21	0.063	I.S.	I.S.	0.040
CCB	0.077	22.6	0.003	0.198	0.765	4.130
DT	0.162	15.3	0.523	0.417	1.37	0.370
DB	0.093	72.9	0.023	0.466	1.24	4.000
DCT	0.277	17.5	0.024	I.S.	I.S.	0.080
DCB	0.084	52.3	0.010	0.357	0.861	4.79
NT	0.097	16.7	0.280	0.704	3.06	0.690
NB	0.065	185.7	0.019	0.363	1.15	5.09
NCB	0.057	184.7	0.011	0.432	0.988	5.69
NCT	I.S.	19.4	0.015	0.355	0.861	0.070
PT	0.131	46.3	0.644	I.S.	4.59	0.010
PB	0.245	76.5	0.054	0.973	2.42	5.39
PCT	0.088	22.5	0.011	0.556	3.38	0.050
PCB	0.060	42.7	0.006	0.890	2.61	4.19

Table 36. Phase II data summary after 20.3 cm (8 inches) of applied water.

Sample Date: 11/24/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	O-PO_4 mg/l	Total P mg/l	Liters Effluent
CT	0.060	9.25	0.082	0.411	0.586	0.745
CB	0.060	18.3	0.021	0.208	0.313	1.69
CCT	0.144	7.53	I.S.	0.097	I.S.	0.040
CCB	0.066	18.0	0.004	0.151	0.198	4.13
DT	0.095	13.4	0.265	0.450	0.662	0.370
DB	0.094	69.8	0.038	0.414	0.752	4.00
DCT	I.S.	10.4	I.S.	0.151	0.962	0.080
DCB	0.105	45.3	0.008	0.326	N.A.	4.78
NT	0.089	14.6	0.231	0.792	1.04	0.690
NB	0.068	128	0.027	0.356	0.385	5.09
NCB	0.063	69.8	0.012	0.389	N.A.	5.69
NCT	0.055	14.4	I.S.	0.326	0.526	0.070
PT	0.134	25.6	0.465	0.958	I.S.	0.010
PB	0.206	89.5	0.051	0.928	1.10	5.39
PCT	0.109	12.8	I.S.	0.462	I.S.	0.050
PCB	0.070	69.4	0.008	1.15	1.55	4.19

Table 37. Phase II data summary after 25.4 cm (10 inches) of applied water.

Sample Date: 12/1/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	O-PO_4 mg/l	Total P mg/l	Liters Effluent
CT	0.026	15.5	0.001	0.394	0.806	0.445
CB	0.048	16.5	0.004	0.214	0.271	Overflow
CCT	0.042	5.83	I.S.	0.079	I.S.	0.040
CCB	0.055	19.4	0.006	0.140	0.230	3.15
DT	0.086	7.68	0.071	0.709	1.02	0.220
DB	0.072	46.9	0.006	0.353	0.378	Overflow
DCT	0.025	10.2	I.S.	I.S.	I.S.	0.040
DCB	0.061	40.2	0.008	0.375	0.416	4.23
NT	0.065	5.69	0.010	0.787	1.04	0.600
NB	0.048	68.4	0.015	0.356	0.397	4.46
NCB	0.048	33.4	0.008	0.447	0.447	4.54
NCT	0.026	5.69	I.S.	0.409	I.S.	0.090
PT	0.045	31.8	I.S.	0.921	I.S.	0.060
PB	0.133	68.2	0.031	1.01	1.18	4.86
PCT	0.042	17.3	I.S.	0.539	I.S.	0.120
PCB	0.091	46.9	0.008	0.945	1.67	3.49

Table 38. Phase II data summary after 30.5 cm (12 inches) of applied water.

Sample Date: 12/9/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	O-PO_4 mg/l	Total P mg/l	Liters Effluent
CT	0.060	6.09	N.A.	0.486	N.A.	0.290
CB	0.069	14.1	0.002	0.230	0.365	1.000
CCT	0.077	4.98	I.S.	0.198	I.S.	0.040
CCB	0.034	12.7	0.002	0.152	0.246	4.74
DT	0.058	9.49	0.049	0.605	I.S.	0.270
DB	0.082	32.6	0.004	0.443	0.551	3.750
DCT	0.043	7.02	I.S.	0.208	I.S.	0.060
DCB	0.058	33.4	0.005	0.410	0.536	4.83
NT	0.039	6.59	N.A.	0.901	2.10	0.590
NB	0.068	33.0	0.013	0.420	0.536	4.65
NCB	0.067	17.5	0.010	0.499	0.580	5.96
NCT	0.057	6.38	I.S.	0.552	I.S.	0.120
PT	0.045	15.8	I.S.	1.132	I.S.	0.135
PB	0.142	68.5	0.031	1.48	1.44	4.98
PCT	0.065	13.7	I.S.	0.69	I.S.	0.130
PCB	0.061	31.2	0.003	1.25	N.A.	2.19

Table 39. Phase II data summary after 35.6 cm (14 inches) of applied water.

Sample Date: 12/15/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	$O\text{-}PO_4$ mg/l	Total P mg/l	Liters Effluent
CT	0.031	4.58	N.A.	0.443	0.806	0.560
CB	0.043	15.4	N.A.	0.214	0.254	1.900
CCT	0.039	5.97	N.A.	0.076	I.S.	0.040
CCB	0.039	18.7	N.A.	0.125	0.202	4.230
DT	0.043	I.S.	N.A.	I.S.	I.S.	0.010
DB	0.065	42.5	N.A.	0.275	0.267	1.700
DCT	0.040	6.96	N.A.	0.153	I.S.	0.160
DCB	0.079	34.1	N.A.	0.336	0.403	5.120
NT	0.037	5.43	N.A.	0.802	1.291	0.580
NB	0.042	28.6	N.A.	0.360	0.440	4.420
NCB	0.039	12.4	N.A.	0.443	0.465	N.A.
NCT	0.039	6.29	N.A.	0.360	I.S.	0.120
PT	I.S.	15.2	N.A.	0.878	I.S.	0.120
PB	0.103	58.10	N.A.	1.07	1.13	4.560
PCT	I.S.	I.S.	N.A.	I.S.	I.S.	I.S.
PCB	0.044	26.21	N.A.	0.931	1.12	N.A.

Table 40. Phase II data summary after 40.6 cm (16 inches) of applied water.

Sample Date: 12/22/75

Sample	Parameter					
	NH_3 mg/l	NO_3 mg/l	NO_2^- mg/l	$O\text{-}PO_4$ mg/l	Total P mg/l	Liters Effluent
CT	0.034	5.53	N.A.	0.426	0.288	0.635
CB	0.032	11.4	N.A.	0.174	0.259	1.685
CCT	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
CCB	0.024	17.5	N.A.	0.127	0.166	4.65
DT	0.078	5.60	N.A.	0.561	0.812	0.198
DB	0.086	N.A.	N.A.	0.271	0.338	1.54
DCT	0.054	6.89	N.A.	I.S.	0.463	0.195
DCB	0.078	N.A.	N.A.	0.288	0.344	5.10
NT	0.040	4.15	N.A.	0.685	0.456	0.625
NB	0.053	22.5	N.A.	0.337	0.406	3.92
NCB	0.038	10.4	N.A.	0.388	0.463	4.170
NCT	I.S.	N.A.	N.A.	I.S.	N.A.	0.075
PT	I.S.	N.A.	N.A.	N.A.	N.A.	0.060
PB	0.072	49.1	N.A.	1.030	0.594	4.37
PCT	0.094	15.7	N.A.	0.466	1.30	0.185
PCB	0.056	27.3	N.A.	0.889	0.556	3.96

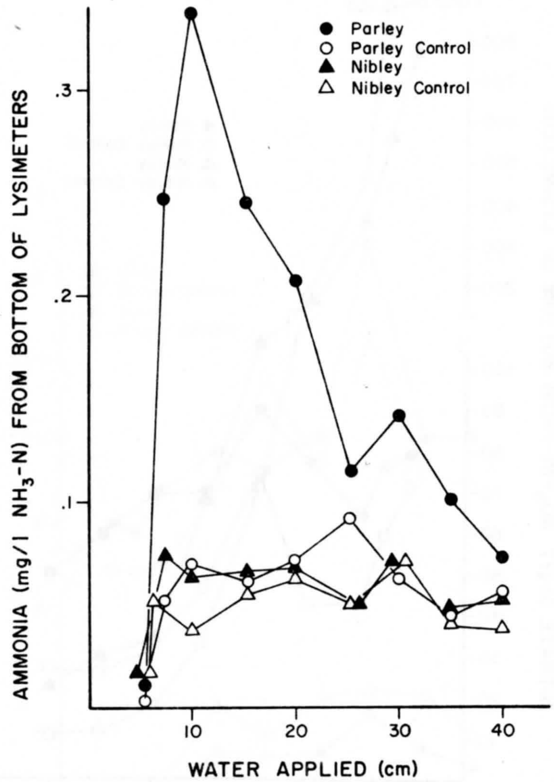

Figure 31. Ammonia concentrations from the bottom of the Parley and Nibley lysimeters.

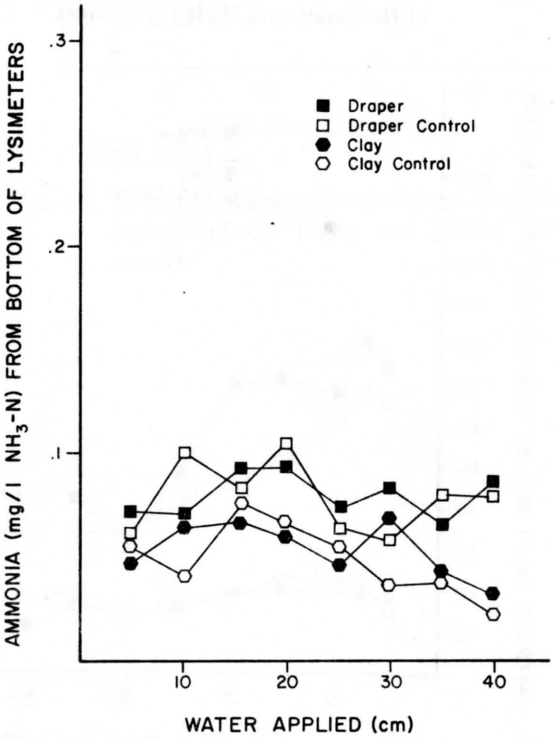

Figure 32. Ammonia concentrations from the bottom of the Draper and Clay lysimeters.

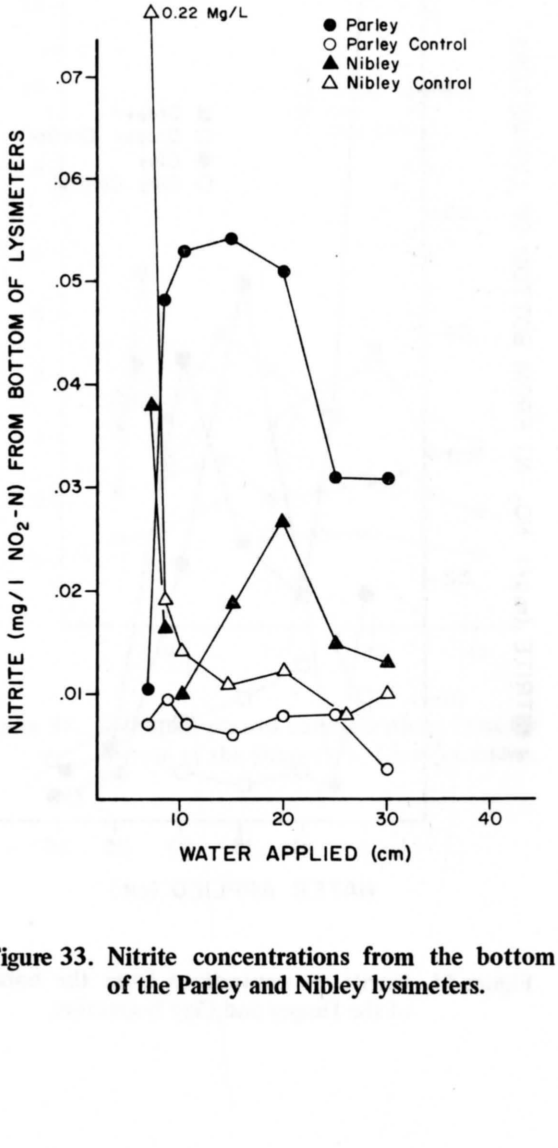

Figure 33. Nitrite concentrations from the bottom of the Parley and Nibley lysimeters.

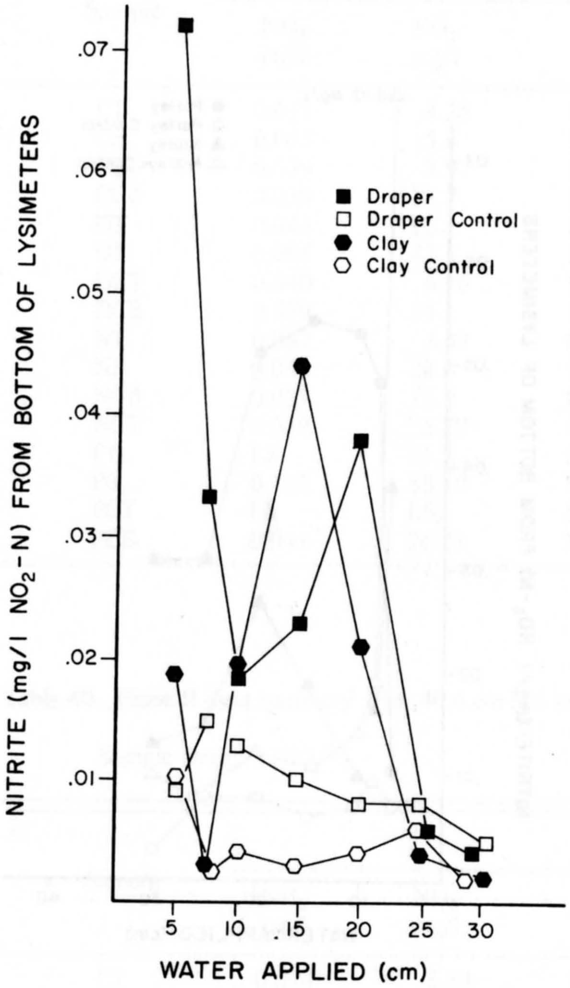

Figure 34. Nitrite concentrations from the bottom of the Draper and Clay lysimeters.

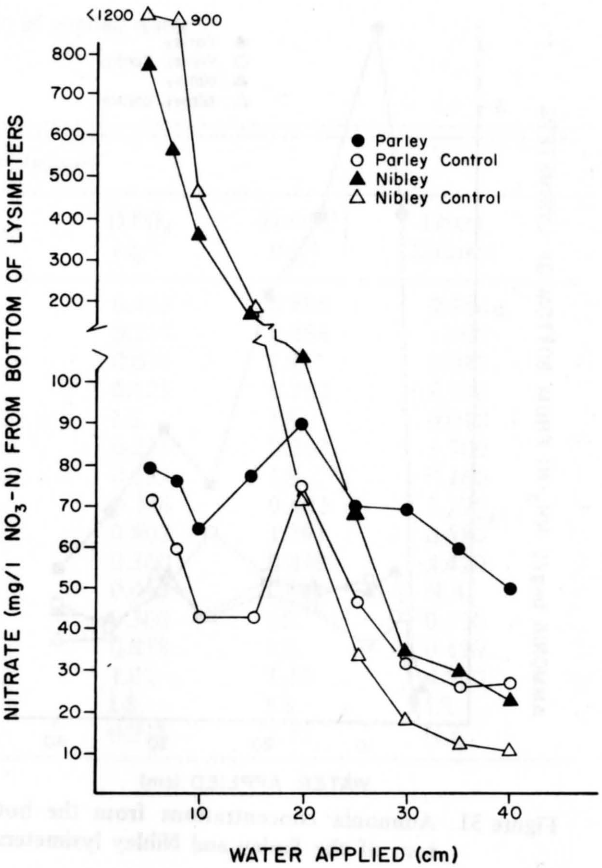

Figure 35. Nitrate concentrations from the bottom of the Parley and Nibley lysimeters.

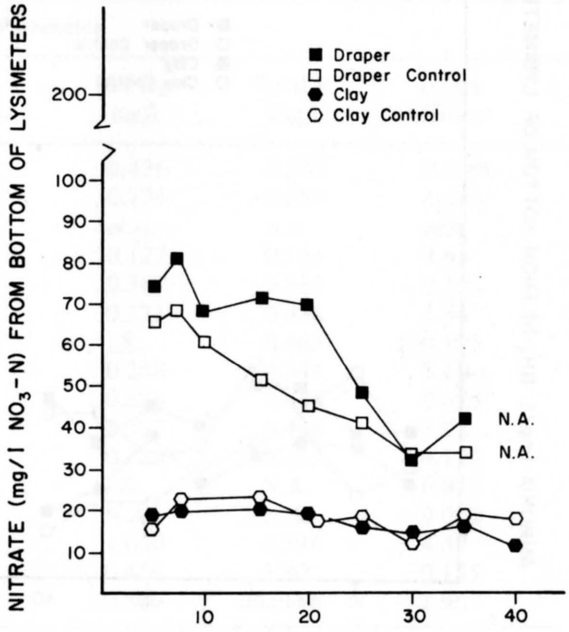

Figure 36. Nitrate concentrations from the bottom of the Draper and Clay lysimeters.

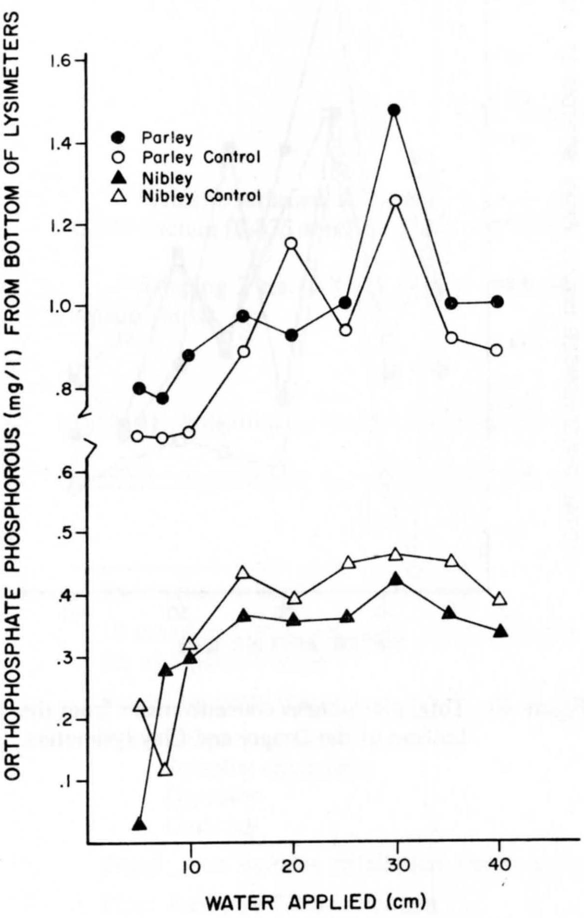

Figure 37. Orthophosphorus concentrations from the bottom of the Parley and Nibley lysimeters.

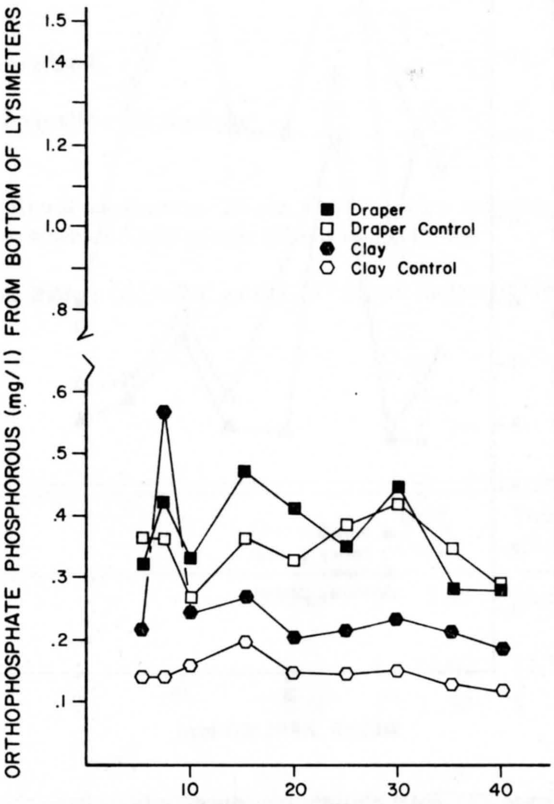

Figure 38. Orthophosphorus concentrations from the bottom of the Draper and Clay lysimeters.

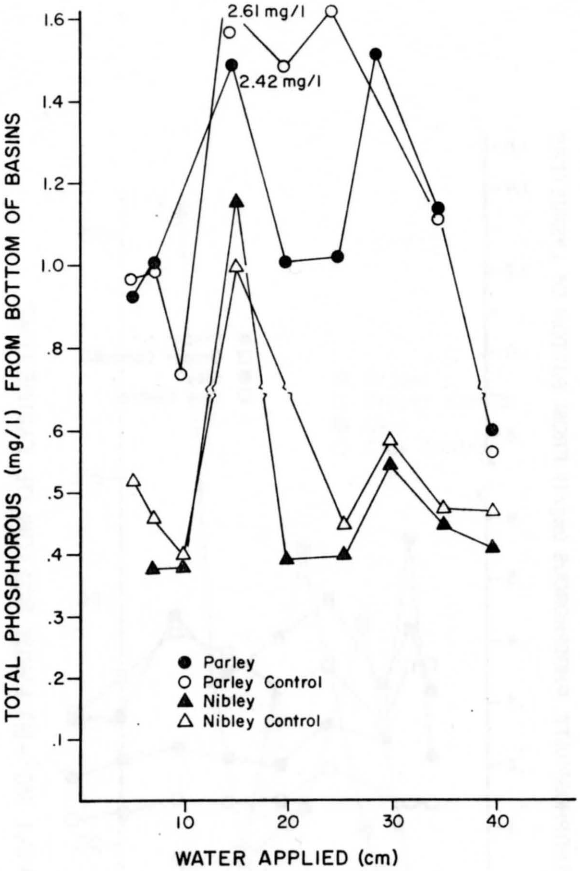

Figure 39. Total phosphorus concentrations from the bottom of the Parley and Nibley lysimeters.

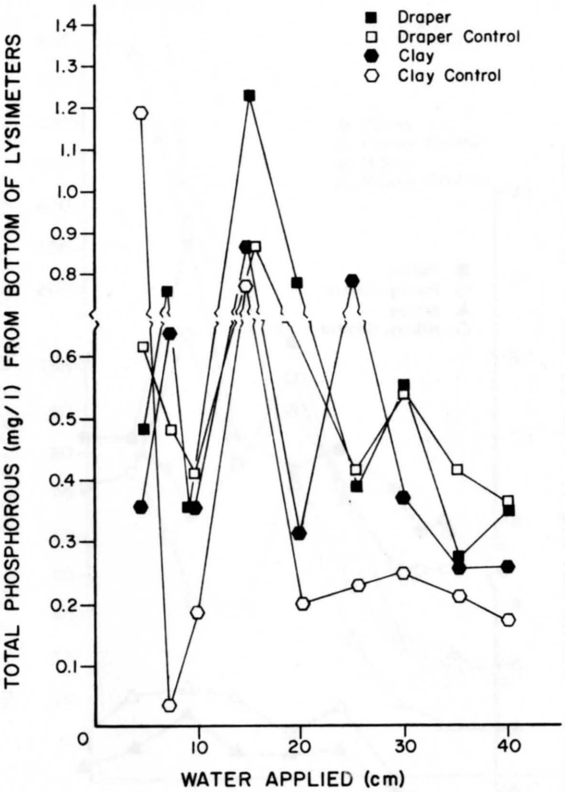

Figure 40. Total phosphorus concentrations from the bottom of the Draper and Clay lysimeters.

Appendix C

Cost Estimate Irrigation Technique

Effluent returned to lagoon or used for agricultural application–20 cm (7.9 in.) deep irrigation beds, 0.337 hectare (0.835 acre) filtration bed–sufficient for town of 5,000 people (Harris et al., 1975).

Scraping 2 cm (0.8 in.) of sand gives 47.4 cubic meters (63 cubic yards) 237 square meters needed (283 square yards).

Table 41. Irrigation technique cost summary.

Item	Quantity	Unit Cost	Total Cost
Excavation of Dirt	230 m^3	$ 5.00	$1,150
10 cm (4 in.) thick concrete for washing basin. Set at 5 percent slope	30	$ 37.60	$1,130
Screen for basin (expanded iron)	100 ft^2	$ .50	$ 50
Filter scraping operation			
Scraping equipment	4/yr	$ 13.00	
Operator	4/yr	$ 7.00	
Cost/day	4/yr	$ 160.00	$ 640
Pump: cost includes installation, panel, and pump house	1	$2500.00	$2,500
Pipe: feed pipe 7 cm aluminum	150 m	$ 1.52	$ 250
10 cm aluminum effluent pipe	150 m	$ 2.13	$ 350
Sprinkler heads and pipe			$ 160
Land	0.3	$1000.00	$ 300
Total			$6,530

Amortization at 7 percent
Land: 100 yr life 300 (0.07008) = $ 21
Pipe, Pump, Pump house:
30 yr life 3260 (0.08059) = 263
Cement basin: 50 yr life 1,130 (0.07246) = 82
Screen and expanded metal: 10 yr life 50 (0.14238) = 7
$373/yr

Total cost per year = 373 + 640 = $1,113

Table 42. Cost estimate for land application and soil amendment.

Item	Quantity	Unit Cost	Total Cost
Equipment: same as for scraping (Table 41)	4/yr	$160	$ 640
Hauling: 40 miles round trip to disposal site		$.30 mi	385
Operator	4/yr	$8/hr	320
Cost of purchasing replacement sand	190 m^3	$5.00	950
Total disposal cost			$2295/yr
If sand sold as fertilizer	400 lb N	$25/100 lbs	$ 100
Total disposal cost if sold as fertilizer			$2195
Total disposal cost if hauling done by purchaser (640 + 950)			$1590/yr