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Stormwater Treatment at Critical Areas

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Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

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This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Abstract

This is one volume in the report series entitled "Stormwater Treatment at Critical Areas" and describes the work conducted on filtration media for stormwater treatment between 1994 and 1996. Other volumes in this report series describe the results of field investigations to determine sources of urban stormwater runoff pollutants, field investigations of storm drain inlet devices, and development of a prototype treatment device that could be installed at the storm drain inlet in critical source areas.

Filtration, especially 'slow' filtration, is of interest for stormwater runoff treatment because filters will work on intermittent flows without significant loss of capability. This work was initially planned to be the optimization of a sand filter to be installed in the filter chamber of the Multi-Chambered Treatment Train (MCTT). However, the poor removals provided by newly constructed sand filters led to the investigation of other media that had the potential to more 'permanently' retain pollutants.

Stormwater filters currently in operation typically use the following media – sand, compost, and peat. This research tested the capabilities of the media currently in use, plus others with known filtering capability (activated carbon, zeolite, a cotton milling waste, and a wood waste), in both controlled laboratory and field conditions. Influent and effluent samples from each filter column were analyzed for toxicity, turbidity, conductivity, pH, major anions and cations, and particle size distribution for each test.

This research demonstrated that physical clogging of the filters occurred well before the sorptive capacity of most media is reached when stormwater runoff is filtered without adequate pre-treatment. If adequate pre-settling is done, the solids remaining in the runoff are generally very small (colloidal). These filters are capable of removing many of the colloidal sized particles; however, the percent removals (measured as suspended solids removal) are smaller when there are fewer larger particles in the influent. Testing using laboratory-scale columns showed that an activated carbon-sand filter is the best at removing the stormwater pollutants. The range of cumulative suspended solids loadings is from 200 g/m^2 (peat-sand) to 2,000 g/m^2 (carbon-sand) before the hydraulic capacity is reduced to 1 m/day. Because these tests were performed using small columns (4.76 cm diameter and 45.72 cm depth) and were not able to completely dry between most of the tests, it is expected that the suspended solids loadings in full-scale filters will be about five times greater than these values before the filter clogs.

In terms of chemical capacity, results of the testing showed that the activated carbon, peat moss, zeolite and compost were the most efficient media at removing the toxicants from the runoff and retaining them during subsequent flushings with clean distilled water. Sand, the most common filtering media currently in use, effectively removed toxicants from the runoff; however, the effluent from subsequent distilled water flushings through newly constructed sand filters indicated that the toxicants were displaced from their "trapped" pores by the water. The flushing effluent was significantly more toxic than the flushing influent clean water. Based on historical full-scale installations, aged sand, after being exposed to field conditions for some time, apparently ripens due to deposition of organic and mineral material and can be much more effective that when first installed. The compost, although an effective filter, added an undesirable color to its effluent. The peat moss, also an effective filter, increased the turbidity of and added color to the runoff. The activated carbon was found to be the most effective at removing the toxicants while not increasing the turbidity and color. In all cases, the media had to be mixed with sand to maintain adequate flow rates.

Research is continuing regarding the ability of filters to treat stormwater runoff and it is anticipated that a future volume in this series will detail the results of the ongoing work. This new phase of the filter project has two purposes: 1) quantify the effects that pH, ionic strength and influent concentration will have on the removal ability and capacity of the filter media; and 2) perform pilot-scale studies using several selected media in order to determine the applicability of the bench-scale results to full-scale operations.

These two steps are required in order to develop design guidelines for stormwater filters that will be useful for the engineering community and stormwater management planners.

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- Shirley Clark's *Evaluation of Filtration Media for the Treatment of Stormwater* (1996),
- Brian Robertson's *Evaluation of a Multi-Chambered Treatment Train for Treatment of Stormwater Runoff from Critical Pollutant Source Areas* (1995),
- Ali Ayyoubi's *Physical Treatment of Urban Storm Water Runoff Toxicants* (1993), and
- Patricia Barron's *Characterization of Polynuclear Aromatic Hydrocarbons in Urban Runoff* (1990).

Much of the material in this report was previously presented in these theses, which also contain considerable additional supporting information.

The authors would also like to thank the following for donation of materials to the project: Polar Supply Company, Inc. of Anchorage, Alaska for donating Gunderboom filter fabric material, Emcon North West of Bothell, Washington for the EMCON fabric, Stormwater Management, Inc. of Portland, Oregon for donating the compost media, RAM Services, Inc. of Birmingham, Alabama for the Enretech, and Forest Products Lab of the U.S. Forest Service for the agrofiber.

Chapter 1
Introduction

Infiltration of stormwater runoff into soil has long been an accepted practice for the disposal of stormwater and replenishment of groundwaters in many locations in the United States. With the advent of urbanization, many of the natural infiltration areas have disappeared permanently, due to both covering the land with pavement and buildings and to the regrading and compacting that accompanies construction. Along with the decrease in area available for infiltration, the volume of runoff from urban areas has increased, as has the runoff's pollutant loadings. Some of this urban runoff may not be suitable for replenishing groundwater due to its pollutant loading from the surfaces over which it flows. Investigation of treatment systems for this runoff is an on-going process; however, there is little information available that compares the various treatment devices. Two recent works that compare the performance of some of the treatment devices are Claytor and Schueler's *Design of Stormwater Filtering Systems* (1996) and Herrera Environmental Consultants' work for the City of Bellevue, WA (1991 and 1995).

Because of the manner in which storm drainage systems are designed and constructed, the untreated runoff from problem areas is combined at its inflow point to the storm sewer system with runoff already in the system. This combined runoff typically is directly discharged into surface waters, or occasionally to groundwaters. It is unlikely to be treated prior to discharge to either surface or ground receiving waters. Even if the runoff were to be treated at the 'end of the pipe' prior to its discharge, the volume of runoff is so large that treatment facilities would be very expensive to construct and maintain. In some locations, stormwater runoff is combined with sanitary wastewater and the combined flow is directed toward the municipal wastewater treatment plant. However, in most cities with these combined sewers, the volume of water to be treated during and immediately following a rain event is too large to be completely treated. Much of the combined sewage bypasses the treatment plant (combined sewer overflow 'CSO') and may be only partially treated (e.g., coarse screening and disinfected) before discharge. Treating runoff from critical source areas before it is combined with runoff from other areas is more cost effective.

To prevent harm either to the surface waters or to the groundwater, the stormwater runoff from problem or critical source areas or stormwater hotspots needs to be treated. Stormwater hotspots are those places where generation of significantly higher concentrations of hydrocarbons, toxic trace metals, or other toxicants and pollutants may occur. Examples of these hotspots include the following: airport deicing facilities, auto recyclers/junkyards, commercial garden nurseries, parking lots, vehicle fueling and maintenance stations, bus or truck (fleet) storage areas, industrial rooftops, marinas, outdoor transfer facilities, public works storage areas, and vehicle and equipment washing/steam cleaning facilities (Bannerman, *et al.* 1993; Pitt, *et al.* 1995; Claytor and Schueler 1996). Rather than treating the large volume of runoff at the end of the pipe, one potentially cost-effective approach is to treat the runoff from the specific problem sources before it mixes with the runoff from the majority of 'non-problem' areas, such as residential developments, institutional developments, and non-industrial rooftops (Pitt, *et al.* 1995; Claytor and Schueler 1996). Single, small point-source treatment devices have been developed and are currently being marketed. Most of these treatment devices, however, are designed to remove settleable solids, not colloidal or soluble pollutants. Only recently have these in-line treatment devices begun to use filtration as a planned treatment step to remove the colloidal and soluble pollutants.

Characteristics of Urban Runoff

Urban runoff is comprised of many different flow phases, such as dry-weather base flows, stormwater runoff, nonstormwater and inappropriate entries, combined sewer overflows (CSOs), sanitary wastewater and snowmelt. The relative magnitudes of each phase's volume vary considerably, based on many factors. Season (cold versus warm weather, or dry versus wet weather) and land use have been identified as important factors affecting base flow and stormwater runoff quality.

Land development increases stormwater runoff volumes and pollutant concentrations. Impervious surfaces, such as rooftops, driveways, sidewalks and roads, reduce infiltration of rainfall and runoff into the ground, increase runoff quantity, and degrade runoff quality. The most important hydraulic factors affecting urban runoff volume (and therefore the amount of water available for infiltration) is the quantity of rain and the extent of impervious surfaces directly connected to a water body or a drainage system. Directly connected impervious surfaces include paved streets, driveways, and parking areas draining to curb-and-gutter drainage systems, and roofs draining directly to a storm or combined sewer. Generally, the 5-day biochemical oxygen demand (BOD_5) and nutrient concentrations in stormwater are lower than in raw sanitary wastewater; they are closer in quality to treated sanitary wastewaters. However, urban stormwater has relatively high concentrations of bacteria, as well as high concentrations of many metallic and some organic toxicants.

Table 1 presents older stormwater runoff quality data while Tables 2 and 3 summarize the stormwater data collected as part of the Nationwide Urban Runoff Program (NURP) from approximately 1979 to 1982. The NURP data is the most comprehensive runoff quality data available on a nationwide basis. These two data sets highlight the important effects that land use and source areas (parking areas, rooftops, streets, landscaped areas, etc.) have on stormwater runoff quality.

Table 1. Characteristics of stormwater runoff (Source: APWA 1969)

Location	BOD_5 (mg/L)	Total solids (mg/L)	Suspended solids (SS) (mg/L)	Chloride (mg/L)	COD (mg/L)
East Bay Sanitation District, Oakland, CA					
Minimum	3	726	16	300	
Maximum	7,700		4,400	10,260	
Average	87	1,401	613	5,100	
Cincinnati, OH					
Maximum seasonal means	12	260			110
Average	17		227		111
Los Angeles County Average 1962-63	161	2,909		199	
Washington, DC catch-basin (rain)					
Minimum	6		26	11	
Maximum	625		36,250	160	
Average	126		2,100	42	
Seattle, WA	10[a]				
Oxney, England	100[a]	2,045[a]			
Moscow, U.S.S.R.	186-285	1,000-3,500[a]			
Leningrad, U.S.S.R.[c]	36	14,541			
Stockholm, Sweden	17-80	30-8,000			18-3,100
Pretoria, South Africa[c]					
Residential	30				29
Business	34				28
Detroit, Michigan	96-234	310-914	102-213[b]		

[a] Maximum [b] Mean [c] Single value reported for study (value not designated as mean or maximum)

BOD: biochemical oxygen demand COD: chemical oxygen demand

Because some municipalities and water management districts want to use this runoff as a recharge water source for groundwater, there is a need for effective pretreatment of it prior to groundwater recharge (National Academy of Sciences 1994; Pitt, *et al.* 1995). Reviews of the research being done on direct infiltration of urban runoff has shown that contamination of groundwater has occurred by infiltration of urban runoff containing the following problem substances:

- Nutrients
- Organics and Pesticides
- Pathogenic Microorganisms

- Metals
- Solids (Suspended and Dissolved)

Table 2. Median stormwater pollutant concentrations for all sites by land use (Nationwide Urban Runoff Program, NURP) (Source: EPA 1983)

Pollutant	Residential		Mixed land use		Commercial		Open/nonurban	
	Median	COV[1]	Median	COV[1]	Median	COV[1]	Median	COV[1]
BOD_5, mg/L	10	0.41	7.8	0.52	9.3	0.31	--	--
COD, mg/L	73	0.55	65	0.58	57	0.39	40	0.78
TSS, mg/L	101	0.96	67	1.14	69	0.85	70	2.92
TKN, μg/L	1900	0.73	1288	0.50	1179	0.43	965	1.00
NO_2+NO_3 (as N) μg/L	736	0.83	558	0.67	572	0.48	543	0.91
Total P, μg/L	383	0.69	163	0.75	201	0.67	121	1.66
Soluble P, μg/L	143	0.46	56	0.75	80	0.71	26	2.11
Total Lead, μg/L	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper, μg/L	33	0.99	27	1.32	29	0.81	--	--
Total Zinc, μg/L	135	0.84	154	0.78	226	1.07	195	0.66

[1] COV = coefficient of variation = $\frac{\text{standard deviation}}{\text{mean}}$ TKN: Total Kjeldahl nitrogen P: phosphorus

Table 3. Summary of NURP priority pollutant analyses* (Source: EPA 1983)

Pollutant	Frequency of detection (%)	Range of detected concentrations (μg/L)
Pesticides		
α - BHC	20	0.0027 to 0.1
γ - BHC (lindane)	15	0.007 to 0.1
Chlordane	17	0.01 to 10
α - Endosulfan	19	0.008 to 0.2
Metals and cyanide		
Antimony	13	2.6 to 23
Arsenic	52	1 to 51
Beryllium	12	1 to 49
Cadmium	48	0.1 to 14
Chromium	58	1 to 190
Copper	91	1 to 100
Cyanides	23	2 to 300
Lead	94	6 to 460
Mercury	10	0.6 to 1.2
Nickel	43	1 to 182
Selenium	11	2 to 77
Zinc	94	10 to 2400
PCBs and related compounds	None detected in >1% of samples	
Halogenated aliphatics		
Methylene chloride	11	5 to 15
Ethers	None detected in any samples	
Monocyclic aromatics	None detected in >6% of samples	
Phenols and Cresols		
Phenol	14	1 to 13
Pentachlorophenol	19	1 to 115
4-Nitrophenol	10	1 to 37
Phthalate esters		
Bis(2-ethylhexyl)phthalate	22	4 to 62
Polycyclic aromatic hydrocarbons		
Chrysene	10	0.6 to 10
Fluoranthene	16	0.3 to 21
Phenanthrene	12	0.3 to 10
Pyrene	15	0.3 to 16

* Based on 121 samples from 17 cities. This table contains only those compounds found in >10% of outfall samples.

Nutrients

Nitrogen- and phosphorus-containing compounds are found in urban runoff primarily from highways. Nitrates result both from vehicular exhaust on the road itself and adjacent soils from fertilization of landscaped areas beside the roads (Hampson 1986; Schiffer 1989; German 1989). Nitrate (NO_3^{2-}) is very soluble and does not sorb well to soil components during infiltration (Spalding and Kitchen 1988). Table 2 shows that the highest concentrations of nitrogen-containing compounds, measured both as total Kjeldahl nitrogen (TKN), and nitrite plus nitrate ($NO_2 + NO_3$), found in urban runoff in the NURP study were from residential areas. This most likely results from regular fertilization and watering of residential lawns.

Highway runoff also contains phosphorus from motor oils, fertilizers, bird droppings, and animal remains (Hampson 1986; Schiffer 1989; German 1989). Phosphorus tends to sorb to soil components during infiltration, thus preventing phosphorus from reaching the groundwater (Crites 1985). However, as the sorption sites fill, i.e., the cation exchange capacity of the soil is exceeded, and phosphorus removal decreases (White and Dornbush 1988).

Organics and Pesticides

Nationwide testing during NURP did not indicate any significant regional differences in the toxicants detected, or in their concentrations (EPA 1983). However, land use (especially residential versus industrial areas) has been found to be a significant factor in toxicant concentrations and yields. Concentrations of many urban runoff toxicants have exceeded the EPA water quality criteria for human health protection by large amounts.

Pesticides are used in urban areas for weed and insect control along roadsides, in parks, on golf courses, and on private lawns. Pesticides (e.g., α-BHC, γ-BHC, chlordane, and α-Endosulfan) are mostly found in dry-weather flows from residential areas (Pitt and McLean 1986), and have been related in some locations to the amount of impervious cover and to the distance the runoff must travel before infiltration (Lager 1977; Pruitt, *et al.* 1985; Butler 1987; German 1989; Domagalski and Dubrovsky 1992; Wilson, *et al.* 1990). Pesticides reach groundwater when their residence time in soils is less than the time required to filter them or biologically or chemically convert them (Jury, *et al.* 1983).

The appearance of organics in groundwater, like elevated concentrations of nitrates (NO_3^{2-}), has been used as an indicator of groundwater contamination in heavily industrial areas (Lloyd, *et al.* 1988). Most organics are either removed or reduced in concentration during percolation through the soil. Groundwater contamination occurs most readily in areas with pervious soils, such as sand and gravel, and where the distance to the aquifer is small (Troutman, *et al.* 1984). Although organics are also commonly found in stormwater runoff from residential and commercial areas, runoff from industrial areas has been shown to contain higher concentrations of certain organics, such as pentachlorophenol and bis(2-ethylhexyl) phthalate, and some of the polycyclic aromatic hydrocarbons (PAHs) (chrysene, fluoranthene, phenanthrene, and pyrene) (Pitt and McLean 1986).

The concentrations of many of these toxic pollutants exceeded the U.S. EPA water quality criteria for human health protection by large amounts. As an example, typical standards for PAHs in surface waters used as drinking water supplies are 0.0028 µg/L (EPA 1986). As shown in Table 4, urban runoff concentrations of chrysene (0.6 to 10 µg/L), fluoranthene (0.3 to 21 µg/L), phenanthrene (0.3 to 10 µg/L), and pyrene (0.3 to 16 µg/L) (four of the most common PAHs found in urban runoff) were reported to be from 100 to as much as several thousand times greater than this criteria.

Pathogenic Microorganisms

Most bacterial characterization of urban runoff has focused on fecal coliforms, mainly because of their historical use in water quality standards. However, many researchers have concluded that, for many reasons, the fecal coliform test is not a reliable test for accurately assessing the pathogenicity of recreational waters receiving urban runoff from storm sewers with no known source of contamination. Pathogenic bacteria routinely have been found in urban runoff at many different locations (Pitt 1983).

Table 4. Toxic organic source area observations (Source: Pitt, *et al.* 1995)

Toxicant	Maximum (μg/L)	Detection Frequency (%)	Significant sources
Benzo(a) anthracene	60	12	Gasoline, wood preservative
Benzo(b) fluoranthene	226	17	Gasoline, motor oils
Benzo(k) fluoranthene	221	17	Gasoline, bitumen, oils
Benzo(a) pyrene	300	17	Asphalt, gasoline, oils
Fluoranthene	128	23	Oils, gasoline, wood preservative
Naphthalene	296	13	Coal tar, gasoline, insecticides
Phenanthrene	69	10	Oils, gasoline, coal tar
Pyrene	102	19	Oils, gasoline, bitumen, coal tar, wood preservative
Chlordane	2.2	13	Insecticide
Butyl benzyl phthalate	128	12	Plasticizer
Bis(2-chloroethyl) ether	204	14	Fumigant, solvents, insecticides, paints, lacquers, varnishes
Bis (2-chloro-isopropyl) ether	217	14	Pesticides
1,3-Dichlorobenzene	120	23	Pesticides

Historically, fecal coliform limits of less than 200 organisms/100 mL have been recommended because the detection frequency for *Salmonella* has been found to increase sharply in waters receiving sanitary sewer discharges when the fecal coliform number exceeds this standard. The occurrence of *Salmonella* in urban runoff is generally low, with reported densities ranging between less than one to ten organisms/100 mL when it is detected; however, numerous urban runoff studies have not detected any *Salmonella*. The occurrence of *Salmonella* in urban runoff at these concentrations generally is not considered to be a health hazard because the required infective dose is greater than these concentrations. *Salmonella* observations have not been found to correlate well with fecal coliform observations, illustrating the poor quality of the fecal coliform test for assessing pathogenicity of the runoff (Pitt 1983).

Urban runoff has also been found to contain other pathogens whose required infective dose is much smaller than that of *Salmonella* or whose mode-of-entry is not ingestion. These pathogens include, but are not limited to, *Pseudomonas aeruginosa*, *Staphyloccus aureous*, *Escheria coli*, *Shigella*, or enteroviruses. *Shigella* species causing bacillary dysentery are one of the primary human-enteric-disease-producing bacteria present in water. *Pseudomonas* is reported to be the most abundant pathogenic bacteria organism in urban runoff and streams, with several thousand *P. aeruginosa* organisms per 100 mL being common (Olivieri, *et al.* 1977). Relatively small populations of *P. aeruginosa* are reported to be capable of causing water-contact health problems ("swimmers ear" and skin infections), and *P. aeruginosa* is resistant to antibiotics. The results of several epidemiologic studies on the health effects of pathogens in urban runoff have been referenced in Field, et al. (1993). One recent cohort study of beachgoers in Santa Monica found that swimmers near (0 – 45 m) a stormwater outfall showed an increased risk of fever, chills, ear discharge, vomiting, gastrointestinal illness, and respiratory disease (Haile, et al. 1996). Pathogenic *E. coli* can also be commonly found in urban runoff (Pitt 1983).

Viruses also are potentially harmful pathogens in urban runoff. Very small viral concentrations are capable of producing infections or diseases, especially when compared to the large numbers of bacterial organisms required for infection. Viruses are usually detected, but at low levels, in urban receiving waters and stormwater (Pitt 1983).

Infiltration will increase bacterial and viral penetration into the soil profile. Like the organics, the greatest chance for contamination occurs when the distance to the groundwater is small (Boggess 1975). Most, but not all, pathogens are usually filtered out or inactivated during percolation through the soil (Gerba and Haas 1988). However, should these pathogens reach the groundwater, they may persist from several hours to several years, depending on the environmental conditions and on the pathogenic species (Goldschmid 1974; Crites 1985; Ku and Simmons 1986; Wellings 1988; Jansons, *et al.* 1989; Tim and Mostaghim 1991).

Metals

The heavy metals of most concern in urban runoff are lead, zinc, copper, nickel, and chromium. Most of these heavy metals have very low solubilities at the typical pH of receiving waters. They are either removed by sediment adsorption or are organically complexed with other particulates (Hampson 1986) and are easily removed during filtration. Metals in urban runoff originate both at industrial sites and on highways, etc., as part of the exhaust and other residue left by vehicular use (Lloyd, *et al.* 1988). Metals seem to be more prevalent in stormwater runoff from industrial areas, although they are also commonly found in runoff from residential and commercial areas. High concentrations of many of the heavy metals found in industrial area runoff were found during both dry and wet weather conditions (Pitt and McLean 1986). Table 5 lists the maximum concentration and the maximum mean concentration (highest average concentration) of several heavy metals in urban runoff, as well as the land use of the area draining to the sampling location (e.g., roof areas, parking areas, storage areas, street runoff, loading docks, vehicle service areas, landscaped areas, urban creeks and detention ponds).

Table 5. Heavy metal source area concentrations (Source: Pitt, *et al.* 1995)

Toxicants	Concentration (µg/L)	Source area
Cadmium		
Maximum[a]	220	Street runoff
Maximum mean[b]	37	Street runoff
Chromium		
Maximum[a]	710	Urban receiving water
Maximum mean[b]	85	Roof runoff
Copper		
Maximum[a]	1830	Urban receiving water
Maximum mean[b]	290	Storage area runoff
Lead		
Maximum[a]	330	Storage area runoff
Maximum mean[b]	105	Storage area runoff
Nickel		
Maximum[a]	170	Parking area runoff
Maximum mean[b]	87	Landscaped area runoff
Zinc		
Maximum[a]	13100	Roof runoff
Maximum mean[b]	1730	Roof runoff

a Maximum concentration detected of all land uses
b Maximum mean is the highest of the mean values reported for each land use

Solids

Suspended solids are of concern in runoff because of their ability to clog infiltration areas (Crites 1985) and treatment devices that use filtration. During percolation, the suspended and colloidal particles that were not stopped at the surface travel downward until they are trapped by pores of sufficiently small diameter. Fine to medium textured soils remove essentially all of the suspended solids by straining, while coarse textured soils allow deeper penetration of these particles (Bouwer 1985; Treweek 1985). If the ground water table is close to the surface and the soil does not provide adequate filtration, the suspended particles will enter the aquifer and increase the turbidity and pollutant content of the groundwater.

Dissolved solids are in urban runoff due to the use of salt to de-ice roads in the winter and due to fertilizer and pesticide salts from the use of those items on residential lawns, parks, golf courses, and roadsides (Merkel, *et al.* 1988). Most salts are not removed during percolation through the soil or through a filter media. In fact, the dissolved solids concentration in groundwater tends to increase due to the leaching of salts out of the soils (Nightingale and Bianchi 1977). In general, once contamination with salts begins, the rapid movement of salts occurs (moving as fast as the groundwater) and the concentration does not decrease until the source is removed (Higgins 1984).

Urban Snowmelt Water Quality

For many years, emphasis was placed on the study and control of stormwater runoff pollution while other urban runoff sources, such as snowmelt, received little attention. However, a large percentage of the annual runoff in northern climates comes from snowmelt, and in urban areas with seasonal snow cover, snowmelt runoff may contribute significantly to the pollution of streams, lakes and rivers.

The limited studies that are available on snowmelt runoff have shown that the median concentrations of pollutants in snowmelt are not strikingly different from the NURP average concentrations, except for chloride, some solids, and bacteria concentrations. The few studies that have examined both cold weather and warm weather runoff at the same urban outfall have demonstrated that snowmelt runoff contains approximately the same concentration of pollutants as rain runoff, with the exception of higher dissolved solids concentrations, as chlorides, in the snowmelt due to road salting. In addition, phosphorous concentrations appear to be consistently lower in snowmelt than in urban rainfall runoff. Results from several investigations that examined both warm and cold weather runoff are presented in Table 6.

Bacteria data are not shown in Table 6, but they have been shown to be significantly lower in snowmelt compared to warm weather rainfall runoff. Pitt and McLean (1986) found that fecal coliforms, fecal streptococci, and *Pseudomonas aeruginosa* populations were significantly lower (by about ten fold) in cold weather runoff compared to warm weather runoff. The Municipality of Anchorage has been studying the bacteriological quality of its surface water resources over several years and also has found that winter coliform measurements are almost exclusively lower than in warm weather runoff (Jokela 1990).

When it rains on a snowpack, heavy pollutant loads can be produced because both soluble and particulate pollutants are flushed simultaneously from the snowpack and from deposited sediment on the urban surfaces such as roads, parking lots, roofs, and saturated soil surfaces. The intensity of runoff from a rain-on-snow event is usually much greater than during a summer thunderstorm because the ground is saturated or frozen (minimal infiltration), and the rapidly melting snowpack also provides added runoff volume (Oberts 1994). During monitoring in Toronto, Pitt and McLean (1986) found that rainfall on an existing snowpack contributed over 80% of the total cold weather runoff volume.

Much of the high dissolved solids concentrations in snowmelt can be attributed to high chloride levels. Year-round monitoring of pollutants has been conducted at the Monroe Street detention pond in Madison, WI, from 1986 to 1988 (House, *et al.* 1993). Chloride levels were found to decrease dramatically between February and April. February runoff samples typically contained 1,000 to 3,000 mg/L chloride, but decreased to less than 100 mg/L by the end of April. Snowmelt chloride concentrations during the next winter rose again to over 1,000 mg/L.

Pollutant Concentrations in Snowmelt Sheetflows

Pitt and McLean (1986), during analysis of snowmelt sheetflows from residential and urban catchments in Toronto, found that, in general, source areas exhibit similar water quality patterns during both rain and snowmelt events. For example, the highest concentrations of lead and zinc in both snowmelt and rainfall runoff were found in samples collected from paved areas and roads.

Fecal coliforms and suspended solids, however, showed significant differences between snowmelt and rainfall runoff. Fecal coliform counts were significantly higher on sidewalks and on, or near, roads during snowmelt periods compared to warm weather periods, even though the outfall fecal coliform counts during the winter were much less than during warm weather. It is likely that dogs, and hence their feces, stayed in areas that were generally free of snow. In warm weather, dogs would be less likely to be restricted to these areas. Cold weather sheetflow median suspended solids concentrations in grass and open areas (80 mg/L) were much less than the concentrations observed during warm weather runoff (250 mg/L). Total solids in snowmelt sheetflows in grass or bare open areas also were reduced dramatically compared to warm weather runoff, probably because snowmelt has significantly less erosion energy than rain. Grass and open areas generally are located relatively far from the drainage system and particles from these areas are not easily transported long distances during periods of low energy. In contrast to the grass and open areas, in road-sheetflow samples, total solids concentrations were greater during snowmelt periods, likely due to the large amount of road sanding debris and high chlorides near roads that was relatively easy to transport in the gutter and drain systems.

Roadways generally contributed the most pollutants (yields and concentrations) to snowmelt runoff. Pitt and McLean (1986) analyzed snow samples along a snowpack transect perpendicular to a road. These data showed that the pollutant levels dropped dramatically at greater distances from the roadway. At distances greater than about 3 to 5 meters from the edge of the roadway, the snowpack pollutant concentrations were relatively constant.

Snowmelt Quality Summary

The following conclusions were obtained after reviewing numerous studies that have investigated urban snowmelt quality:

- Urban snowmelt runoff quality is similar in nature to stormwater runoff quality from the same source area, except for dissolved solids and chlorides (much higher), and bacteria (much lower).
- The high dissolved solids concentrations in snowmelt result from the high chloride quantities used in road salting.
- Atmospheric scavenging of air pollutants by snowflakes is the source of only a small fraction of the snowmelt pollutants.
- Most of the contamination of snow occurs after it is on the ground. Snow becomes polluted while it accumulates for long periods in snowpacks. Snowmelt runoff picks up few pollutants as it flows over the various urban surfaces. However, rainfall on an existing snowpack causes most of the snowpack-related discharges.
- Roads, parking lots and storage areas are important pollutant sources in all land uses during snowmelt periods. In residential areas, yards and open areas are also major sources of nutrients.

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Table 6. Comparison of snowmelt and rainfall runoff quality (concentrations in mg/L)

		Suspended solids			Dissolved solids			COD			Ref.
Location	Land use	Snow-melt	rain runoff	$\frac{\text{Snow}}{\text{Rain}}$	Snow-melt	rain runoff	$\frac{\text{snow}}{\text{rain}}$	Snow-melt	rain runoff	$\frac{\text{snow}}{\text{rain}}$	
Toronto, Ontario	Residential (median values)	30	22	1.4	1530	230	6.7	40	55	0.7	1
Toronto, Ontario	Industrial (median values)	95	117	0.8	1240	208	6.0	94	106	0.9	1
Bayreuth, Germany	Urban roof & street (range)	39- 495	4-296	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2
Topeka, KS	Resident & commercial (median)	27	362	0.1	1380	232	5.9	34	46	0.7	3
Topeka, KS	Agriculture (median values)	10	671	0.02	592	232	2.6	19	40	0.5	3
Milwaukee, WI	Residential (mean values)	1-398	N/A	N/A	N/A	N/A	N/A	250	38	6.6	4
Milwaukee, WI	Commercial (mean values)	N/A	N/A	N/A	N/A	N/A	N/A	203	81	2.5	4
Boulder, CO	Residential & commercial (range)	1- 1229	24-3730	N/A	N/A	N/A	N/A	8-936	9-1557	N/A	5

		pH			Total Kjeldahl N			Total phosphorus			Ref.
Location	Land use	Snow-melt	rain runoff	$\frac{\text{Snow}}{\text{Rain}}$	Snow-melt	rain runoff	$\frac{\text{snow}}{\text{rain}}$	Snow-melt	rain runoff	$\frac{\text{snow}}{\text{rain}}$	
Toronto, Ontario	Residential (median values)	N/A	N/A	N/A	0.17	2.5	0.07	0.23	0.28	0.8	1
Toronto, Ontario	Industrial (median values)	N/A	N/A	N/A	2.5	2.0	1.3	0.50	0.75	0.7	1
Bayreuth, Germany	Urban roof & street (range)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2
Topeka, KS	Resident & commercial (median)	N/A	N/A	N/A	1.8	2.1	0.9	0.14	0.36	0.4	3
Topeka, KS	Agriculture (median values)	N/A	N/A	N/A	1.5	1.8	0.8	2.0	0.79	2.5	3
Milwaukee, WI	Residential (mean values range)	6.7- 8.1	N/A	N/A	3.3	2.2	1.5	0.17	0.26	0.6	4
Milwaukee, WI	Commercial (mean values range)	5.7- 8.2	N/A	N/A	3.3	1.9	1.7	0.20	0.28	0.7	4
Boulder, CO	Resid. & commercial (range)	N/A	N/A	N/A	0.22 -5.4	1.7- 3.7	N/A	0.6- 3.3	0.2-7	N/A	5

		Copper			Lead			Zinc			
Location	Land use	Snow-melt	rain runoff	$\frac{\text{Snow}}{\text{Rain}}$	Snow-melt	rain runoff	$\frac{\text{snow}}{\text{rain}}$	Snow-melt	rain runoff	$\frac{\text{snow}}{\text{rain}}$	Ref.
Toronto, Ontario	Resident. (median values)	0.04	0.03	1.3	0.09	0.06	1.5	0.12	0.06	2.0	1
Toronto, Ontario	Industrial (median values)	0.07	0.06	1.2	0.08	0.08	1.0	0.31	0.19	1.6	1
Bayreuth, Germany	Urban roof & street (range)	0.03-0.15	0.01-0.11	N/A	0.02-0.16	0.005 - 0.14	N/A	0.24-1.18	0.07-1.17	N/A	2
Topeka, KS	Resident & commercial (median)	0.005	0.02	0.3	0.035	0.07	0.5	0.055	0.11	0.5	3
Topeka, KS	Agriculture (median values)	0.01	0.02	0.5	N/A	0.02	N/A	0.01	0.06	0.2	3
Milwaukee, WI	Residential (median values)	N/A	N/A	N/A	0.12	0.12	N/A	N/A	N/A	N/A	4
Milwaukee, WI	Commercial (median values)	N/A	N/A	N/A	0.27	0.52	N/A	N/A	N/A	N/A	4
Boulder, CO	Residential & commercial (range)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5

Reference 1. Pitt and McLean 1986.
Reference 2. Daub, *et al.* 1994.
Reference 3. Pope and Bevans 1984.
Reference 4. Novotny 1986.
Reference 5. Bennett, *et al.* 1981.

Filterable (Dissolved) Fraction of Stormwater Pollutants

Table 7 summarizes the filterable (dissolved) fraction of toxicants found in stormwater runoff sheet flows from many urban areas (Pitt, *et al.* 1995). Pollutants that occur mostly in a filterable form have a greater potential of affecting the groundwater and are more difficult to control using conventional stormwater control practices, sedimentation and sand filtration. Fortunately, most of the toxic organics and metals are associated with the non-filterable fraction (suspended solids) of the runoff. However, probable exceptions to this rule include zinc, fluoranthene, pyrene, and 1,3-dichlorobenzene. In general, dry weather flows in storm drainage systems tend to have much higher concentrations of the toxicants in the filterable fraction.

Table 7. Reported filterable (dissolved) fractions of stormwater toxicants (Source: Pitt, *et al.* 1995)

Constituent	Filterable Fraction (%)
Cadmium	20 to 50
Chromium	<10
Copper	<20
Iron	Generally < 20, but can be higher
Lead	<20
Nickel	Generally < 20, but can be higher
Zinc	>50
Benzo (a) anthracene	None found in filtered fraction
Fluoranthene	65
Naphthalene	25
Phenanthrene	None found in filtered fraction
Pyrene	95
Chlordane	None found in filtered fraction
Butyl benzyl phthalate	Irregular
Bis (2-chloroethyl) ether	Irregular
Bis (2-chlrorisopropyl) ether	None found in filtered fraction
1,3-dichlorobenzene	75

Sources of Stormwater Pollutants

Harmful constituents in stormwater may originate in a variety of sources. High bacterial populations have been found in sidewalk, road, and some bare ground sheetflow samples collected from locations where dogs would most likely be "walked." Tables 4 and 5 summarize toxicant concentrations and likely sources or locations having some of the highest concentrations detected (Pitt, *et al.* 1995). The detection frequencies for the heavy metals are all close to 100 percent for all source areas, while the detection frequencies for the organics shown ranged from about 10 to 25 percent. Vehicle service areas had the greatest abundance of observed organics, with landscaped areas having many of the observed organics. Residential source areas can contribute a significant variety of toxic metals and organics to the runoff, as is shown in Table 8. However, because the contribution of any single residence is generally small and typically does not have the variety of chemicals listed in Table 8, attempting to treat the runoff from residential source areas on a residence-by-residence basis is not feasible.

One reason that many of the chemicals listed in Table 8 and in prior tables do not vary much between the land uses is that a major contributor to baseline pollution in all urban runoff is atmospheric deposition of airborne pollutants. Airborne pollutants land indiscriminately in a watershed and where they land is determined by the wind's dispersion ability and the pollutant's nature at the time of discharge into the atmosphere. Thus, the runoff loading from a watershed is a combination of the atmospheric deposition baseline across the watershed (independent of land use) and the additional pollutant release from individual locations in the watershed. It is these additional pollutant loadings that are related to land use and are of concern.

Based upon a review of the data collected during the NURP program and by other stormwater researchers, the control of small critical area contributions to urban runoff ('hotspots') may be the more cost-effective approach for treatment/reduction of stormwater toxicants. The general features of the critical source areas appear to be large paved areas, heavy vehicular traffic or areas with many vehicular starts, and the outdoor use and/or storage of problem pollutants. Using these general guidelines, the problem point source areas identified for this work are industrial manufacturing facilities, service stations, vehicle maintenance facilities, and some other commercial developments. Residential runoff is relatively innocuous and is well below the national average concentration in runoff for most hydrocarbons, metals and priority pollutants, although it is a major contributor of several conventional stormwater pollutants including solids/sediment, total phosphorus, and bacteria. Residential runoff usually is not a problem in a watershed because residential areas contribute smaller unit area volumes of runoff and because the runoff concentration is relatively low.

Table 8. Urban runoff hazardous and toxic substances* (Sources: Galvin and Moore 1982; EPA 1983; Pitt and McLean 1986)

Residential Areas	Industrial Areas
Bis(2-Ethylene)phthalate	1,2-Dichloroethene
Phenol	Methylene Chloride
Butylbenzyl phthalate	Tetrachloroethylene
Di-N-butyl phthalate	Butylbenzylphthalate
Benzene	Di-N-butyl phthalate
BHC	Phenanthrene
Chlordane	Pyrene
Dieldrin	Benzene
Endosulfan Sulfate	Chloroform
Endrin	Ethylbenzene
Isophorone	n-Nitrosodimethylamine
Methoxychlor	Toluene
Pentachlorophenol	PCB-1254
Aluminum	PCB-1260
Copper	Pentachlorophenol
Lead	Phenol
Zinc	Aluminum
Cadmium	Chromium
Other Heavy Metals	Lead
	Other Heavy Metals

* Substances found in ≥10% of stormwater analyzed.

Stormwater Runoff Treatment Media

Most stormwater treatment devices currently in use or in development use sedimentation as their primary pollutant removal mechanism since most of the pollutants in runoff are associated with the particulates. Filtration may also be used as a second step because the contaminated particulates are strained out as the water passes through the filter bed and either are trapped on the surface of the filter or among the media's pores. Filtration is very effective, as it can achieve 90% removal of particles between 6 and 41 µm. However, filtration/straining alone cannot remove soluble pollutants (Pitt, *et al.* 1995; Claytor and Schueler 1996). Several comparisons have been done between filtration and other devices for stormwater runoff treatment. The first comparison is to look at the feasibility of each type of treatment device. The results are given in Table 9. The comparison of pollutant removal capabilities is given in Table 10.

Table 9. Stormwater treatment device characteristics (Source: Claytor and Schueler 1996)

Criterion	Ponds	Wetlands	Infiltration	Filters
Soils	Most	Most	Soil-dependent	All
Drainage area	10 Acres min.	10 Acre min.	2-5 Acre max.	2-5 Acre max.
Head	0.9-1.8 m	0.3-1.8 m	0.6-1.2 m	0.3-2.4 m
Space	2-3% Site	3-5% Site	2-3% Site	2-7% Site
Cost/Acre^a	Low	Moderate	High	Mod-High
Water Table	No Restrictions	No Restrictions	1.2 m below	0.6 m below
Cleanout	2-10 yrs.	2-5 yrs.	1-2 yrs.	1-3 yrs.
Life	20-50 yrs.	20-50 yrs.	1-5 yrs.	5-20 yrs. (estimated)

a No dollar figures given by Claytor and Schueler

Table 10. Runoff treatment pollutant removal capabilities (Source: Claytor and Schueler 1996)

Pollutant	Ponds	Wetlands	Infiltration	Filters[a]
Sediment	Excellent	Excellent	Excellent	Excellent
Phosphorus	High	High	Excellent	Fair-High
Nitrogen	Fair	Fair	High	Fair
Soluble Nutrients	High	Fair	High	Low
Bacteria	Low-High	Unknown	unknown	Low-High
Hydrocarbons	High	High	unknown	Excellent
Trace Metals	Fair	Fair-Excellent	High	Fair-Excellent

Low: 0-25% removal *Fair*: 26-50% removal *High*: 51-75% removal *Excellent*: 76% + removal

a Includes both organic and sand filters. Sand filter removal efficiency at lower end of range for phosphorus and trace metals. Organic filters have higher removal efficiencies for many trace metals and bacteria, although some organic filter media will leach nutrients. See detailed descriptions of each media in literature review.

Filtration can be defined as an interaction between a suspension and a filtering material (Ives 1990). Pollutants are removed from the solution when they become attached to the media or to previously captured particles. In general, the three key properties of a filter are surface area, depth and profile. Filter performance is measured by effluent water quality (traditionally, turbidity and suspended solids concentration, as well as particle counts and dissolved organic carbon concentration [DOC]), water production (unit filter run volume), and head-loss development (rate and time to back wash), all of which change over time (Clark, *et al.* 1992; Tobiason, *et al.* 1993).

Surface area loading is usually given as the percentage of the total impervious area draining to the filter, compared to the filter surface area. The filters examined during this research would require about 1% of the impervious drainage area. The surface area required for any filter depends upon the media type and the rainfall patterns for the area. The depth of the media is also important with stormwater filter depths usually ranging between eighteen inches and four feet. Shallow bed depths are typically used for both hydraulic and cost reasons because less filtering time and less media are required in a shallow bed. However, the tradeoff for shallow filter depth is usually effluent quality, i.e., the shallower the filter, the less removal that is likely to occur. In general, filtering systems should be sized using the volume of runoff to be filtered, and filtering media selected based upon the pollutants of interest.

The performance of filters that are also adsorbers or ion-exchangers is measured by the change in concentration of the constituents of interest as a result of filtration. Filtration performance depends on the source water quality (types and concentration of natural organic matter and suspended particles), any required chemical additions and mixing processes, and physical characteristics of the media (type, size distribution, depth, and hydraulic loading rate) (Tobiason, *et al.* 1993). Although not likely to be significant for most stormwater filters, two fluid properties that can affect filtration are viscosity and density. Density and viscosity are both temperature dependent, and density will also depend upon the concentration of dissolved solids in the water (Clark 1990). In stormwater runoff treatment, viscosity variations in the runoff between areas is insignificant because the water would be either as viscous as ice or as non-viscous as steam before the viscosity change would affect the filter's performance. Density changes may have a larger effect on filtration of runoff because it is also dependent upon the dissolved solids concentration. This effect, however, is only likely to be noticeable for filters receiving snowmelt runoff. In general, the biggest control on a filter's overall performance is the concentration of previously deposited particles (Tobiason, *et al.* 1993).

Properties of the media that can affect filtration performance include straining ability, adsorption/ion-exchange ability, available microbial action, and plant resistance and uptake. These last two properties are usually only important in stormwater filters that have a steady water supply and a thriving, but well-maintained, plant cover. For other filters, only the first two properties are of interest in filtration design. The chemical properties of media that are good ion-exchange or adsorption agents include a high organic content or clay, a high cation exchange capacity (CEC), and a neutral to alkaline pH. Pure sand has minimal adsorption capacity; however, once the filter ages and a biofilm covers the sand grains, the sand filter is capable of excellent adsorption when the pH conditions are in the correct range. This pH dependence is also present in organic media.

Microbial action is very important in many filtration processes. It used to be believed that stormwater filters dried out between storms when the interevent dry period was several days and that this drying of the media would prevent the formation of an effective microbial colony. Research has shown, however, that the media (especially the organic media) do not dry out between storms, and a microbial colony is established in areas of the filter where there is a sufficient organic carbon source. Two of the more important microbial processes in filtration are nitrification and denitrification. Nitrification converts organic nitrogen to ammonia and the ammonia to nitrite followed by nitrate. Denitrification converts the nitrate to nitrogen gas, which is released to the atmosphere. Research on stormwater filters currently in use indicates that significant nitrification is occurring in the filters, and the concentration of nitrate in the effluent is greater than it was in the influent. Denitrification pockets have been located in some stormwater filters; however, denitrification does not occur to a sufficient degree. Because of the concern over nutrients (e.g., nitrates) entering surface waters, some new filters are being constructed to provide a denitrification zone. The ability to denitrify to an appreciable extent requires that a filter section be anaerobic. This is usually done by providing a saturated zone at the bottom of the filter, where several inches of gravel remain submerged, even when the rest of the filter dries out. In order to keep the filter working appropriately (most other beneficial microbial action requires an aerobic environment), the submerged area should be separated from the rest of the filter by several inches of dry gravel (Claytor and Schueler 1996).

The media described below are the media of interest for this research. These media have been selected because of their prior use in either stormwater or wastewater treatment devices, or both. A comparison of the pollutant removal pathways for different media is in Table 11. The only difference between sand filters and other media is the ability of the organic media to act as an ion-exchange resin. Both sand and organic filters currently in use have a pretreatment area that is a sedimentation chamber and that slows the runoff velocity. Both media strain out particles to the size limit imposed by the pores of the media. Sand can adsorb pollutants once the filter is aged, *i.e.*, when a microbial biofilm has formed on the surface. In order to determine the appropriate filter media, the properties of the individual media must be compared, as they are in Table 12.

Table 11. Filtration media pollutant removal pathways (Source: Claytor and Schueler 1996)

Removal Pathway	Sand Filters	Organic Filters
Sedimentation	In pretreatment cell	In pretreatment cell
Straining	In media	In media
Adsorption	By organics on filter surface	Peat or compost media
Microbial Action	On filter surface	On filter surface
Plant Uptake	None, unless cover crop	None, unless cover crop
Infiltration	None, unless open system	None, unless open system
Dissolved Solids Leaching?	Yes	Yes
Nitrification/ Denitrification	Nitrif.: Yes Denitrif.: No	Nitrif.: Yes Denitrif.: No

Table 12. Physical/chemical properties of filter media (Source: Claytor and Schueler 1996)

Property	Sand	Compost	Peat
Hydraulic Conductivity (cm/hr)	3.3	unknown	0.025-140
Water Holding Capacity (cm/cm)	0.14	unknown	0.01-0.2
Bulk Density (g/cm)	2.65	1-2	<0.1-0.3
pH	N/A	7.8	3.6-6.0
Organic Matter (%)	<1	30-70	80-98
Cation-Exchange Capacity	1-3	66	183-265
Total P (%)	0.0	<0.1	<0.1
Total N (%)	0.0	<1.0	<2.5
Filtration Efficiency after 0.45 m (%)	93	16	47

A review of available literature on the filtration media selected for this project (sand, activated carbon, peat moss, compost, zeolite, Enretech, agrofiber, and filter fabrics) is given in Chapter 2. The literature review focuses on the ability of these various media to remove specific compounds from either water or from a mixed liquid. For those media that have been used in stormwater filters, a review of their effectiveness is also given.

Chapter 3 describes the overall design of the project as well as the procedures followed during each phase of this research:

- Initial Evaluation for the Sand Column
- Effects of Sediment Accumulation on Filter Flow Rate
- Effects of pH and Ionic Strength on Pollutant Removal
- Long-Term Filtration Performance

Included in Chapter 3 are discussion of the laboratory procedures used to analyze the samples as well as the statistical tools used to process the data.

Chapter 4 presents the results of the testing and includes the statistical summaries for each of the parameters investigated during each phase of this project. Table 76 at the end of Chapter 4 summarizes the statistically significant average removal percentages for each media.

Chapter 5 presents the conclusions of this research and includes a brief summary of each medium. These summaries detail the effects of pH and ionic strength on a medium's removal ability as well as a brief review of the medium's performance during long-term testing. At the end of this chapter are three example filter designs. They are provided in order to give the user the opportunity to see how the information in this report would be used in a practical application.

Future Research

The work presented here is the first part of an ongoing effort to investigate the ability of filtration media to treat stormwater runoff. In order to develop effective design criteria for stormwater filters, additional work is required to clarify several issues, including for example:

- Quantification of the effects of pH, ionic strength, and influent concentration on removal ability and media capacity for a pollutant (chemical breakthrough testing);
- Quantification of the effect that filter construction, as it relates to contact time, has on removal ability and media capacity;
- Quantification of scale-up factors that will allow a designer to take the results of bench-scale tests on a filter media and use them in the design of a full-scale filter installation.

Laboratory set-ups would be appropriate for the first two items above. For each media during each test, filtration will continue until chemical breakthrough occurs for each pollutant. Once these tests are complete, several media will be chosen to investigate contact time effects. Contact time will be controlled either by adjusting the sand content of the mixed media section or by restricting the effluent port. Last, pilot-scale filters will be built in 220 L (55 gallon) Nalgene drums. Presettled influent test water will be obtained from detention ponds (as compared to using spiked tap water during some of the bench-scale work) in the Birmingham area and laboratory analyses will be as given in Table 17 (Chapter 3).

Chapter 2
Review of Media Filtration for Stormwater Quality Control

Sand

The use of sand filtration is common for drinking water and sanitary wastewater treatment/effluent polishing. Water supply treatment plants have successfully used sand filtration for many years. Wastewater treatment plants often use sand filtration to polish their effluent before release, especially as the regulatory requirements for the discharge of suspended solids becomes more stringent. Sand filters are also popular as stormwater runoff treatment, especially in urban areas where the filters must be retrofitted and property values decree that the filters be located underground (Claytor and Schueler 1996).

Physical Characteristics

Slow sand filters are characterized by slow filtration rates, an extremely narrow range of sand particle sizes, the lack of chemical pretreatment, relatively long filter runs between cleanings, and surface scraping and sand removal instead of backwashing as a cleaning technique (Collins, *et al.* 1992). Filtration rates are as much as fifty times slower than those of rapid sand filters; consequently, slow sand filters require significantly more surface area in order to filter comparable volumes of water (Crittenden, *et al.* 1993). Slow sand filter media is characterized by certain parameters: size distribution, settling velocity, porosity, grain integrity, shape, hardness (resistance to attrition), and the results of visual and microscopic examinations (Ives 1990). Slow sand filters need to have a minimum vertical distance (or fall) of at least 0.6 m, but preferably 1.5 m, from inflow to outflow to drive the water by gravity through the entire filter (Claytor and Schueler 1996).

Fine sand/silt filters remove particulates by direct straining on the surface of the filter media. The combination of grain size and bed depth will determine the effectiveness of the filter. Naghavi and Malone (1986) demonstrated that the combination of grain size (0.2 mm) and a shallow bed depth produced an average fluorescence removal of approximately 97%, even with no chemical pretreatment. This combination also had the highest initial filtration rate (226 m^3 m^{-2} day^{-1}) and a lower initial headloss (7.3 cm). The effect of media size on filtering ability also was demonstrated by Tobiason, *et al.* (1993) in a 2.5 cm inner diameter (ID) acrylic column filled with 17 cm of 0.4 mm glass beads along with the test suspensions that contained either one size or a mixture of 0.27, 1.3 and 10 μm diameter particles. The use of smaller diameter media affected the rate of removal of larger particles and the rate of head-loss development. Head-loss development was typically linear with time, and, for suspensions of mixed particle sizes, it generally was the same as, or somewhat lower than, head loss for monodisperse suspensions of the smaller-sized particle (Tobiason, *et al.* 1993). Head loss (or hydraulic resistance) is determined by the filter's surface area, which depends on the size and number of grains, not the grains' weight. In order to have the same head loss development pattern in a 'single-size' media filter, the new filter would require a diameter equal to the d_{10} of the mixed-size media (Ives 1990). Head loss results from increased fluid drag, pore constriction, and increased interstitial velocities caused by particle deposition. Small particles cause more head loss because of their high surface area per unit volume (Tobiason, *et al.* 1993). Head loss is spread more evenly through the filter in larger particle diameter media. Therefore, capturing a particle with larger diameter media results in less head loss than capturing it with smaller media (Clark, *et al.* 1992).

Removal is different at the various depths of the filter, with the influent particle concentration being reduced dramatically in the top section of the filter and smaller reductions occurring near the bottom of the filter. This effect is most pronounced for filters with smaller sand sizes; therefore, removal efficiency in the larger media improves substantially compared to the smaller media at each successive depth of the filter. Later in the filter run, large particles apparently are less effectively removed in the top section of the filter, suggesting that small particles entered the filter and were captured by previously retained particles, thereby forming a floc on the media surface. If the flocs break off the surface, they may pass unhindered through the filter media and be measured as larger particles. In addition, particles with surface chemistry favorable for retention in the medium likely are captured in the top section of the filter while the particles with unfavorable surface chemistry reach the lower section where they still are not removed from solution (Clark, *et al.* 1992). Percent removal is a function of both sand depth and particle size; using coarse sand and a deep bed is recommended by Farooq and Al-Yousef (1993) because this type bed will require less cleaning than fine sand in a shallow bed filter.

Filtration velocity, to a lesser extent than media size, affects removal efficiency, bed depth use, and head loss. Head loss is directly proportional to velocity in new filters, but for ripened filter beds, the direct proportionality does not apply. Increased velocity pushes particles deeper into the filter bed prior to capture, thus allowing more of the filter depth to be used in particle capture. This leads to reduced head loss and, therefore, larger quantities of water can be treated before cleaning (Clark, *et al.* 1992). There is, however, an upper limit on filtration velocity. At loading rates higher than 5 m/day of sanitary wastewater, the sand filter clogs within a few days while for loadings less than 1 m/day, collected organic particles decompose in the filter and free up pore space, and the run length on a volume-treated basis is quadrupled (Fujii, *et al.* 1987).

For sand, as for other filter media, the shape of the curve of percent captured versus particle diameter depends on the particle capture mechanism, the filter medium, the fluid being filtered, and the filtration conditions (Shucosky 1987). Generally, dissolved oxygen concentrations and pH decrease in sand filtration. Particulate chemical oxygen demand (COD), particulate organic nitrogen, and particulate phosphorus are removed during filtration, even before the filter is ripened. However, very little of the soluble fraction of the above constituents is removed (Fujii, *et al.* 1987).

Using lateral viewing endoscopes, unexpected phenomena, such as tumbling grain motion and void formation ('wormholes,' or pores larger than a sand particle's diameter), have been observed in traditional sand filters, especially rapid filters or those using countercurrent filtration. These 'wormholes' start with holes in the surface deposit and remain open despite the continuing flow of solids into them. Aggregates, especially those of weakly-bound compounds, that enter the wormholes, even if they are larger than the hole, may be deformed or disrupted by the hole, yet they do not completely stop flow through the hole. This aggregate 'destruction' during filtration only occurs to an appreciable extent when substantial surface deposits are present (Ives 1989). Preferential flow (macropore, fingering, or funneled flow) also has been observed in sand filters, as it has in many other filters and soils. During preferential flow, the fluid follows the local wetting front in wormholes and bypasses the matrix pore space. Filtration efficiency for preferential flow pathways is much smaller than it is for matrix pore flow because flow through preferential pathways is more rapid and less time is available for straining and/or sorption (Steenhuis, *et al.* 1980).

General Removal Capabilities

Slow sand filters are extremely effective in removing suspended particles, and effluent turbidities are consistently below 1.0 NTU. Bacteria, viruses and *Giardia* cysts are also removed with enhanced filtration once a bacterial population is established on the filter. However, sand filters have only a limited ability to remove organic material that are precursors to trihalomethane formation and the biodegradable fraction of dissolved organic carbon (BDOC) (Collins, *et al.* 1992; Eighmy, *et al.* 1992; Farooq and Al-Yousef 1993). Stratified sand filters have been shown to remove enteric viruses, along with total organic carbon (TOC) from septic tank effluent at a loading rate of 0.061m/day, even from sand filters that contained new sand, i.e., had no bacterial biofilm ("schmutzdecke") and, therefore, no bacterial breakdown of pollutants (Gross and Mitchell 1990). A sand filter with an effective grain size of 0.23 mm and a loading rate of 3.84 m/day was shown to effectively remove biochemical oxygen demand (BOD) (86%), suspended solids (68%), turbidity (88%), and total coliform bacteria (99%) from sanitary wastewater (Farooq and Al-Yousef 1993). High algae removal can be accomplished using media with median sand size ≤ 0.2 mm (Naghavi and

Malone 1986). Sand filtration at a Superfund site showed suspended solids removal of about 50% for waters that contained mostly colloidal-sized particles and 80% to 100% removal for waters whose solids were larger. One unexpected result for the filtration was that solids breakthrough occurred much earlier than expected, possibly because the filter was not in continuous operation (Dahab, *et al.* 1991). The presence of wormholes was not investigated by Dahab, *et al.* (1991) although this is one potential explanation for the early breakthrough.

Sand filtration, without modification of the sand by ripening or by adding a surface coating of an adsorber such as manganese or ferric oxide, is not effective at removing dissolved constituents. Deethylatrazine was consistently detected in the effluent of one sand filter (2 cm ID x 30 cm long filter) used to treat natural groundwater spiked with 200 μg/L of atrazine (applied at 5 mL/min for 70 days; 23 m^3 m^{-2} day^{-1}) until the filter ripened, when it was no longer detected (Selim and Wang 1994). Sand filtration also does not remove total suspended solids (TSS) from pulp and paper mill secondary effluent as effectively as it does from municipal secondary effluent, likely because the nature and size of the solids are considerably different (unimodal at 2 μm) from the nature and size of the organisms filtered from secondary wastewater (bimodal at 4 and 85 μm). The pulp and paper mill effluent had mostly very small particles, a range where the sand filter is not as effective (Biskner, *et al.* 1978).

Ripening of the Sand Filter

Ripening is the development of a bacterial biofilm, the 'schmutzdecke,' on the sand filter that improves the removal ability of the filter. This increased efficiency occurs for all particle sizes initially, but eventually only continues for small sizes with the removal efficiency decreasing and possibly becoming negative for larger particles. Captured particles aid in the collection of subsequent particles by partially blocking and restricting passage through the pores. Therefore, the rate of increase in particle removal efficiency depends on the influent particle concentration. When more time elapses between collisions of particles on the media surface and those in solution, the first collected particle may migrate to the bottom of the grain and greatly reduce the opportunity for interaction with the next incoming particle. Thus, the removal efficiency is greater and ripening is quicker when the influent concentration is greater (Clark, *et al.* 1992).

Submicron particles also improve the deposition of larger particles because they increase the apparent surface roughness of the media and/or the large particle (Tobiason, *et al.* 1993). Ripening of the filter creates rougher pore channels, which slows down the flow and provides more contact time between the media and the pollutants in the water (Fujii, *et al.* 1987). In addition, larger particles may hinder the initial deposition of the smaller particles because of unfavorable hydrodynamic interactions or differences in destabilization (Tobiason, *et al.* 1993).

Sand filters have a more limited capacity for substrate growth and thus have a smaller microbial population, as compared to organic media filters of the same size (Selim and Wang 1994). Even when ripening is complete, head-loss development is approximately linear with time (or mass deposited) (Tobiason, *et al.* 1993).

Adsorbent Coatings

Another technique for improving the removal efficiency of a sand filter is by adding an adsorbent coating, usually an iron or manganese oxide, to the sand grains, thus providing adsorption sites for the ions in solution. Potential sorption mechanisms include diffusion into the lattice of the minerals; adsorbing at sites on the sand surface; adsorbing sites on hydrous iron and manganese oxides and hydroxides; and complexing at sites on natural organic matter in the schmutzdecke. The iron oxide coating on sandy soil has been found to bind metals of all sizes very strongly. Metal binding strength is relatively low in the exchangeable fraction (the portion of the pollutant concentration that participates in ion-exchange rather than in complexation or chemisorption) and increases in the non-exchangeable fraction because metals in the non-exchangeable fraction likely are incorporated within the crystalline lattice or strongly sorbed to the mineral surface. The non-exchangeable fraction, therefore, is 'permanently bound' to the sand under normal operating conditions. The non-exchangeable fraction also contains the greatest concentration of sorbed metals, except zinc. The smallest sized media have the greatest mass concentration of metals. Lead binds more strongly to the smaller particles while arsenic, copper, and zinc show similar affinities for all size fractions. Metal sorption kinetics show the existence of both a fast reaction, where metals bind to surface sites, and a slow reaction, where metals bind to interior sites. Reaction kinetics also affect the availability of metals for sorption. Metals from the dissolution of the soluble compounds are available more quickly for sorption while metals in precipitates or other covalently bonded compounds are not (Van Benschoten, *et al.* 1994).

Manganese oxide coatings can remove manganese(II) from solution with the rate of sorption being positively correlated to the number of available surface adsorption sites. Chlorine in the manganese(II)-containing influent will oxidize the adsorbed manganese(II) and, therefore, continually regenerate the filter. Removal efficiency is a function of the surface MnO_x(s) concentration, its oxidation state, and the influent pH. Manganese(II) sorption capacity is greater, and the reaction rate is faster when the influent pH is raised (reducing H^+ ion competition for sites). For a given pH, sorption capacity also is increased as the surface MnO_x(s) concentration is increased. Efficient manganese(II) sorption was found even during the winter when the sorption rates likely are significantly slower. Further research has shown that the coatings do not affect the filter hydraulics either during a run or during cleaning, the clean-bed head loss of the filter, or the effective size and density of the filter media (Knocke, *et al.* 1991).

Limitations

Slow sand filtration has the following limitations and concerns: (1) a limited acceptable range of influents (usually less than two hundred milligrams per liter influent total suspended solids [TSS]); (2) a limited ability to remove organic precursor materials because of a lack of sorption surfaces; and (3) extensive filter downtimes and ripening periods (Collins, *et al.* 1992).

Cleaning and re-ripening a slow sand filter is difficult and time-consuming; however, several techniques have been developed to "speed up" that process. Wet harrowing in West Hartford, CT, removed the surface mat yet kept the biomass in the filter media down to the depth of harrowing (Eighmy, *et al.* 1992). Nonwoven, synthetic fabrics have been placed on the sand surface. The fabric has a greater porosity and specific area and is a more efficient filter for larger particles. The benefits of filter mats/fabrics placed on top of the sand surface are longer run times and simpler cleaning that requires only the removal and cleaning of the fabric. However, a filter cover does not improve the ability of a sand filter to treat raw waters of varying quality, and no suitable cleaning method exists for the fabrics in large-scale installations (Collins, *et al.* 1992).

Stormwater Runoff Treatment

Sand filtration for stormwater treatment began on a large scale in Austin, TX. The Austin sand filters are used both for single sites and for drainage areas less than fifty acres. The filters are designed to hold and treat the first one-half inch of runoff with very good pollutant removal ability.

According to the City of Austin design guidelines, the minimum sand depth should be eighteen inches. These filters may have either gravel, a geotextile, or other fabric on top of the sand to prevent premature clogging with large particles. For a filter built according to Austin's design guidelines, the assumed pollutant removal efficiencies, which are based upon the preliminary results of the City's stormwater monitoring program, are given in Table 13.

In Washington, D.C., sand filters are used both to improve water quality and to slow the runoff in order to prevent large slug inputs to the combined sewer system (CSO). Water quality filters are designed to retain and treat three-tenths to one-half inch of runoff with the exact design based upon the amount of impervious area in the watershed (Shaver 1994).

In Delaware, the sand filter is an acceptable method for achieving the 80% suspended solids reduction requirement. These filters are intended for sites that have impervious areas that will drain directly to the filter, such as fast-food restaurants and gas stations. In many areas, sand filters precede an infiltration device in order to prevent or postpone clogging of the infiltration device. Sand filters are also used on sites where there is no space to retrofit other infiltration devices (Shaver 1994).

Table 13. Pollutant removal efficiencies for sand filters (Source: City of Austin 1988)

Pollutant	Removal Efficiency (%)
Fecal Coliform Bacteria	76
Total Suspended Solids (TSS)	70
Total Nitrogen	21
Total Kheldajl Nitrogen	46
Nitrate – Nitrogen	0
Total Phosphorus	33
Biochemical Oxygen Demand (BOD)	70
Total Organic Carbon	48
Iron	45
Lead	45
Zinc	45

According to Delaware's guidelines, the sand filter can be expected to adequately remove particulates (TSS removal efficiency 75 - 85 %) but not soluble compounds. Studies of a six-year old sand filter in Maryland that was installed at the drain of a heavily-used parking lot showed that the filter is now becoming clogged. Inspection of the sand below the filter surface has shown that oil, grease, and finer sediments have migrated into the filter, but only to a depth of approximately two to three inches (Shaver 1994; Galli 1990).

The sand filter used in Delaware has a similar design to the Austin filters with an eighteen-inch sand depth and a six-inch gravel underdrain. Each filter has a minimum of six to twelve inches of ponding depth/storage head available on top of the filter. Monitoring of a Delaware sand filter which treats the runoff from a 0.28 ha (0.7 acre) section of a parking lot near National Airport in Alexandria, VA, showed that the filter had an average 72% removal of total phosphorus, >80% removal of total suspended solids (influent concentration = 50 mg/L), and >90% removal of zinc (200-630 µg/L influent concentration). The sand filter, which had an underdrain layer, continued to function during freezing weather. Anaerobic conditions will develop in sand filters unless the bottom of the filter is exposed to air. Anaerobic conditions enhance nitrate removal by denitrification but reduce total phosphorus removal because the iron phosphates degrade and release phosphorus (Galli 1990).

Monitoring of a Delaware sand filter at the Alaska Marine Terminal in Seattle showed >80% removal of total petroleum hydrocarbons (TPH) when influent concentrations were 1.2 mg/L and >90% removal of TPH when influent concentrations were 3.1 mg/L. Suspended solids and phosphorus removals were similar to those noted at the National Airport in Alexandria, VA (Galli 1990).

Herrera Environmental Consultants (1991 and 1995) also have evaluated sand filters as a media for stormwater treatment. Their results indicate that sand filters by themselves are the least effective at removing both total phosphorus (0 to 28 percent removal) and soluble phosphorus (0 to 38 percent removal). Iron sand and sand amended with other constituents, such as calcitic lime and hypnum peat, were found to remove significantly more total phosphorus and soluble phosphorus than sand alone. The sand/calcitic lime mixture removed between 29 and 79 percent of the total phosphorus and between 25 and 93 percent of the soluble reactive phosphorus. The sand/hypnum peat mixture removed between 31 and 94 percent of the total phosphorus and 36 to 99 percent of the soluble reactive phosphorus (Herrera Environmental Consultants 1991). The addition of steel wool to the sand filter as an adsorbent showed that it was also an effective sorbent media for total and soluble phosphorus removal. Phosphorus removal occurs because the steel wool oxidizes in the presence of water and oxygen and the oxidized iron easily reacts with the phosphate in solution (Herrera Environmental Consultants 1995).

Urbonas (1999) has broken the stormwater detention and filtration process down into the individual unit processes that occur in a sand filter during suspended solids removal and has provided recommendations for using the information gathered during the unit process analysis to design new sand filter installations. Hydraulic capacity, a function of the suspended solids loading, is the design variable. This approach of Urbonas is novel in stormwater filter design because maintenance is addressed as a design variable in the sizing calculations, i.e., the recurrence interval of maintenance is used in the calculation of the amount of suspended solids removed per square foot of filter surface area.

Activated Carbon

Activated carbon separation has long been used in the water treatment and chemical process industries and in hazardous waste cleanup as an effective method for removing trace organics from a liquid. Activated carbon is made first by charring materials such as almond, coconut and walnut hulls, other woods or coal. The char particles are activated by exposing them to an oxidizing gas at high temperatures. The activation process makes the particles porous which creates a large internal surface area available for adsorption (Metcalf and Eddy 1991).

Organic Removal Capability

Activated carbon has been used for more than fifty years in drinking water treatment plants to remove taste- and odor-causing compounds, along with most synthetic organic chemicals, pesticides, herbicides, color, and trihalomethane precursors (Rael, *et al.* 1995). Disinfection by-products, including the trihalomethane precursors, have also been removed from drinking water by granular activated carbon (GAC) (Crittenden, *et al.* 1993; Abuzald and Nakhla 1994).

Slow GAC filters achieve excellent organic removals (> 90 percent), with the removal efficiency limited by the depth of the filter. This dependence is due to 'slowness' of the transport kinetics and attachment mechanisms inherent in activated carbon sorption. The problem with activated carbon is its exponential head loss curve, *i.e.*, increasing removal increases head loss development rates, and, therefore, the filters must be cleaned more frequently (Collins, *et al.* 1992).

Anaerobic charcoal chip reactors, along with anaerobic sand packed reactors, can remove up to 80% of the chemical oxygen demand (COD) at an organic loading rate of 7 kg COD/m^3-d and 60% at 12 kg COD/m^3-d and were able to withstand a shock loading of over 22 kg COD/m^3-d. However, efficiency dropped when wastewaters contained a high concentration of SO_4^{2-} and Na^+. In general, the removal efficiency of COD is inversely related to loading rates, and no clogging was observed even after one year of operation (Chin 1989).

Granular activated carbon (GAC) is useful for treating wastewaters with inhibitory, yet adsorbable, compounds that make conventional biological treatment difficult or impossible (Fox, *et al.* 1990). Activated carbon can remove both dissolved and synthetic organic carbon (DOC and SOC, respectively) compounds from solution. However, provided that adequate contact time exists in the treatment system, equilibrium capacity of the carbon decreases with decreasing initial DOC or SOC concentration. The SOC adsorption rate onto activated carbon decreases with decreasing initial SOC concentration due to competition by natural organic matter. Equilibrium is achieved after three hours with an initial concentration of 109 µg/L trichlorophenol, yet equilibrium takes twenty-four hours when the initial concentration is 34 µg/L trichlorophenol (Najm, *et al.* 1993). At steady state, activated carbon with a growing microbial colony can remove approximately 40% of the initial DOC from solution by one or more of three independent mechanisms: surface degradation, film degradation, and pore degradation (including in micropores) (Koch, *et al.* 1991). In a test of two carbon types at a Superfund site (wood treatment plant), both carbons had excellent total organic carbon (TOC) removal (minimum 80% removal after 64 bed volumes, influent 320 mg/L TOC). However, the same removal efficiency was not found for waters with an exceptionally high influent TOC concentration (50% removal after 64 bed volumes, influent 900 mg/L TOC) (Dahab, *et al.* 1991) A growing microbial community also is not easily removed during backwashing (Servais, *et al.* 1991).

Pore diffusion appears to control the intraparticle mass transfer rate for DOC with either or both the pore and surface diffusion coefficients being linearly dependent on particle size and with the observed pore diffusion coefficient decreasing over time. Possible reasons for this decrease include the following: (a) the rapid initial diffusion is intraparticle, while the later, slower diffusion is micropore diffusion; (b) the diffusion path length increases as the pores fill; or (c) the displacement of previous adsorbed DOC by more strongly adsorbed DOC causes counter diffusion. Isotherm calculations for DOC sorption onto activated carbon showed that the percent adsorption after 15 days was nearly identical to that of 7 days. Also, it was determined that for a desired effluent concentration of 1 mg/L DOC ($c_e/c_i = 0.4$), the optimum empty bed contact time (EBCT) was between twenty and thirty minutes (Crittenden, *et al.* 1993).

Excellent removal of phenolic compounds from a groundwater spiked with 20 µg/L trichlorophenol (TCP) has been shown for activated carbon. The maximum adsorption capacity is dependent on the influent sorbate concentration, *i.e.*, capacity and rate of adsorption decrease with decreasing influent concentration (13 mg/L PAC dosage needed one hour contact to reach equilibrium [5 µg/L] while 4 mg/L needed a 24 hour contact time). The adsorption efficiency for a floc-blanket reactor was found to be equal to the adsorption efficiency for batch isotherm tests, indicating that a reactor or filter with sufficient contact time can achieve the maximum removal efficiency for the solute of interest. The adsorption rate of TCP onto activated carbon can be described by the homogeneous surface diffusion model (HSDM) in which an adsorbate molecule first diffuses through the carbon particle's stagnant liquid film layer before instantaneously adsorbing to the carbon's outer surface. The adsorbate then slowly diffuses along the carbon pores' inner surfaces (Najm, *et al.* 1993).

However, the capacity of granular activated carbon (GAC) for phenolic compounds in deionized water is decreased under anaerobic conditions. In the presence of oxygen, the TCP likely is converted to different, unmonitored compounds in the effluent. This results in an erroneously high estimation of adsorptive capacity (Adham, *et al.* 1991). Phenol and *o*-cresol undergo oxygen-induced polymerization reactions on activated carbon that increase both the amount adsorbed and the strength of adsorption. The increases are dependent on the dissolved oxygen (DO) concentration. Seventy percent of the adsorbed phenol was recovered from Filtrasorb 400 activated carbon after adsorption under anoxic conditions while only 25% was recovered after adsorption under aerobic conditions, demonstrating that the adsorption under aerobic conditions led to stronger bonding between the phenol and the carbon. The molecular oxygen aids in the formation of acidic surface oxides on the carbon, which enhances dimer and trimer formation on the carbon surface. The polymerization also significantly increases the time required to reach equilibrium because it is the rate-limiting step. Adsorption is then limited by intracrystalline diffusivity rather than external mass transport resistance. For example, adsorption of phenol on Filtrasorb 400 activated carbon took 48 hours to reach equilibrium under anoxic conditions while it took 14 days to reach equilibrium under aerobic conditions. This increase in adsorption capacity in the presence of dissolved oxygen, however, does not hold for aliphatic organic compounds (Abuzald and Nakhla 1994).

Chlorinated phenols are strongly adsorbed by activated carbon; however, biodegradation of these compounds can also occur on the carbon. Anaerobic degradation of the highly chlorinated phenols, *i.e.*, tetra- and pentachlorophenol, will produce various lower chlorinated phenols, *i.e.*, tri-, di-, and monochlorophenols. This biodegradation and adsorption of the chlorinated phenols will occur simultaneously with pH significantly influencing the adsorption of compounds with acidic functional groups. Batch equilibrium adsorption data for eight chlorinated phenols on Calgon Filtrasorb 400 activated carbon in two concentration ranges at pH 7.0 and 30°C showed the adsorptive capacities increasing from pentachlorophenol to the trichlorophenols and holding fairly constant from the trichlorophenols to the monochlorophenols. The adsorptive capacity for the neutral molecules (monochlorophenols dominant) is higher than that for the ionized forms (pentachlorophenols dominant). The chlorine's position on the phenyl ring, however, has little influence on a chlorophenol's adsorption (Nelson and Yang 1995).

The good fit of the Langmuir isotherm to the adsorption data suggests that a fixed number of accessible adsorption sites exists on the carbon for a given range of solute concentrations. A surface complexation model has been proposed in which the carbon's functional groups can be divided into two types: acidic (carboxyl, phenolic, quinonoid, and normal lactone) groups and basic (chromene and pyrone-like) groups. The surface complexation model fits the adsorption data for 2,4,5-trichlorophenol, 2,4-dichlorophenol, and 4-chlorophenol for different pHs. Tests have shown only slight differences between isotherms for 2,4,5-TCP between pH 4.15 and pH 5.22, but significant differences between the isotherms at higher pH (> 6.5). Solution pH less than the pK_a (6.94 for TCP) does not significantly affect the adsorption capacity of the activated carbon, but when the pH is greater than the pK_a, there is a linear decrease in adsorption capacity with the increase in pH (Nelson and Yang 1995).

Benzene in groundwater also can be adsorbed on activated carbon. However, this adsorption may be retarded by one or more of the following reasons: fouling of the carbon by various components in groundwater; differences in adsorption and mass transfer kinetics of the various components; adsorption interference and competition by other compounds in groundwater, such as pesticides and herbicides; and interference by chemicals that precipitate on the carbon. At a benzene concentration of 20 mg/L, adsorption may be limited by film diffusion. However, at higher concentrations (50 mg/L), adsorption is not limited by film diffusion because of the larger concentration gradient available, and because pore diffusion controls the rate of adsorption. Bacterial growth on the carbon surface may be either an advantage or a disadvantage. This strictly depends on the microbial population available (Rael, *et al.* 1995).

It has been demonstrated at both a Superfund site and for an industrial wastewater that activated carbon will remove more than one organic compound from a solution. The Superfund site water contained various phenolic compounds (*i.e.*, pentachlorophenol, 4-methylphenol, and 2,4-dimethylphenol), pyrene, fluoroanthene, and unidentified total organic carbon (TOC), and color-producing compounds that were removed from solution by the carbon. However, competitive adsorption led to lesser adsorption efficiency as compared to the efficiency for pure test compounds (Dahab, *et al.* 1991). Competitive adsorption also reduced the capacity of carbon for the individual organics in the industrial wastewater, as compared to their respective single compound isotherms. Capacity reduction can be correlated with the percent of the total organic carbon (%TOC) in solution contributed by the target compound, *i.e.*, the smaller the %TOC, the larger the capacity reduction, because other compounds are available in sufficient concentration to compete for many of the adsorption sites. Mass transport limitation also can significantly reduce a compound's adsorption capacity, especially for large organic contaminants such as color agents (Ying, *et al.* 1990).

Activated carbon also can remove pesticides from solution. Atrazine and two of its degradation products, deethylatrazine and deisopropylatrazine, have been adsorbed from contaminated groundwater (200 µg/L atrazine filtered at 5 mL/min for 70 days through a 2 cm ID x 30 cm long filter column) (Selim and Wang 1994). A sand filtration/carbon treatment system can reduce a diversity of organophosphate, organochlorine, and pyrethroid pesticide residues down at least to their detection limit. The sand filtration step removes the pesticides associated with particulate matter while the carbon adsorbs the nonparticulate pesticides in the solution. Average removal efficiencies for the total treatment system were 79% for pyrethroids, 92% for organophosphates, and 96% for organochlorines (Moore, *et al.* 1985). Activated carbon filters also can provide a good environment for microorganisms that may biodegrade certain organic molecules. The biodegradation often will increase the apparent adsorptive capacity of the carbon (Selim and Wang 1994).

Inorganic (Non-Metal) Removal Capability

Activated carbon fiber has been shown to remove iodine and iodide compounds from acetic acid in water, methanol, and ethanol solutions. When compared to other conventional adsorbents (activated carbon, silica gel, alumina, NaY zeolite, Ag ion-exchanged NaY zeolite, and Ag ion-exchanged Amberlyst XN 1010), the activated carbon fiber had the greatest adsorptive capacity for the iodine and iodide compounds. Iodine removal was inversely related to iodine's solubility in the solution. The excellent removal by the fiber can be explained by the unique structural characteristics of activated carbon fiber which promote fast adsorption. Since the fiber contains only micropores with a pore diameter less than 2 nm while activated carbon has a broader pore size distribution, the adsorptive capacity is greater for the fiber. This is because the major (stronger) adsorption sites are located only in the micropores with weaker adsorption in the meso- and macropores. Iodine diffusion to the strong binding sites is the rate-limiting step in activated carbon adsorption; this diffusion is eliminated in the fiber because the micropores are on the surface (Yang, *et al.* 1993).

Activated carbon also can reduce chlorite ions to chloride by having the oxychlorine species react with the radical sites, oxygen-containing functional groups, and metal ions on the activated carbon to form the radical entities ClO_2, Cl°, and ClO°. These then form Cl_2O_2, Cl_2O_3, HOCl, etc. with chloride, chlorate ions, and oxygen as final products. Increasing the initial chlorite concentration increases carbon's adsorption capacity for other compounds because the chlorate-forming secondary reactions are favored which increases the concentration of acidic surface functional groups, thus increasing the number and type of sites available for adsorption by not only chlorite but also other compounds. One gram of granular activated carbon removed 600 mg/L of chlorite from solution (Vel Leitner, *et al.* 1994).

The presence of phenol or *p*-nitrophenol in solution or preadsorbed on carbon, however, will decrease its capacity to remove chlorite because many byproducts, such as chlorophenols, *p*-benzoquinone, dimerization, and carboxylation products, are formed on the carbon surface once the chlorite contacts the organics. These halogenation reactions occur in the granular activated carbon (GAC) bed both when the chlorite is in solution with the organics and when the chlorite-free organic solution is passed over chlorite-preoxidized activated carbon. Oxidation of activated carbon with chlorite apparently promotes the catalytic properties of the carbon surface. Other disinfectants such as NH_2Cl, Cl_2, ClO_2 also undergo halogenation reactions with organics in the presence of activated carbon. These byproducts may be less desirable than the organics originally in solution. Some of the byproducts formed from reactions of organics and disinfectants on the activated carbon surface include aromatic acids (benzoic acid, salicylic acid, hydroxynitrobenzoic acid, and nitrobenzoic acid), benzaldehyde, hydroxybenzaldehyde, 4-phenoxyphenol, 4-phenoxymethoxybenzene, 2,2'-dihydroxybiphenyl, benzofuran, 2,3-benzofurandione, chloronitrobenzenes, and nitrosophenol (Vel Leitner, *et al.* 1994).

Metal Removal Capability

Hexavalent chromium is effectively removed by a pH-dependent adsorption with the peak adsorption at pH 6 (Sharma and Forster 1993). More than 80% of inorganic and organic mercury in a solution has been removed by a commercial granular activated carbon, with even greater removals resulting when humic acid or nitrilotriacetic acid (NTA) was added to the solution (initial solution, 10 µg/L Hg(II) and 5 mg/L of humic acid or NTA). Activated carbon from peanut shells is seven times more effective than commercially-available activated carbon at the removal and recovery of mercury from solution, possibly because the peanut hull carbon has a higher moisture content that may increase its porosity and makes available more sorption sites. Peanut hull carbon also has a lower ash/higher carbon content (70 mg peanut hull carbon for adsorption of 20 µg/L in 100 mL solution versus 500 mg commercially available activated carbon for the same adsorption). Peanut hull carbon has lower decolorizing capacity and a moderate ion-exchange capability as compared to the commercially available carbon, implying that it will not be as suitable for organic adsorption. Peanut hull carbon adsorption also is not as pH dependent as commercially-available activated carbon. Rice-husk and coconut-shell activated carbon also has been effective in the removal of heavy metals from aqueous solutions. The adsorption process follows both the Freundlich and Langmuir isotherms with pore diffusion being only one of the rate-controlling steps (Namasivayam and Periasamy 1993).

Microorganism Removal Capability

Historically, it has been believed that silver-impregnated activated carbon rendered bacteria inactive, *i.e.*, made drinking water 'safer,' possibly because low pH, lower temperatures, higher mineral matter, and phosphate concentrations could reduce bacterial action. Testing of a commercial silver-impregnated carbon filter showed that the concentration of *Salmonella typhi* was reduced more than 5 logs (99.999 percent) at a silver concentration of 50 µg/L and 1 hour of exposure; however, the concentration of *Pseudomonas aeruginosa* was reduced less than 50% and the concentration of *poliovirus type 1* was not reduced under the same conditions. Under most circumstances and with long-term use, the silver-impregnated activated carbon filters have negligible ability to remove microorganisms from solution (Bell 1991). Silver has been fused into activated carbon and some ceramic filters in order to prevent biofilm growth in some household water filtration units, e.g., Katadyn water filters.

Other Carbon-Based Filters

Carbonaceous residues such as wheat straw have been used to remove nitrogen from reclaimed wastewater in a nitrification/denitrification sequence. The wheat straw is then a source of carbon for the microbial colonies that perform the nitrification and denitrification. The straw's capacity for nitrogen, ammonia, and nitrate immobilization was found to be about 9 mg N/g (mg nitrogen per gram). Significant reductions in BOD, organic carbon, chlorophyll, phosphorus, algae, and clay concentrations in the influent were also found (Lowengart, *et al.* 1993). The wheat straw substrate has a poor nutrient content that leads to the removal of nitrogen and phosphorus from the influent water by the microbial biomass (Diab, *et al.* 1993).

Ultrafiltration membrane pores (0.001 - 0.1 μm) are relatively large and can remove only those molecules and particles that are larger than the pores. Inorganic ions readily pass through these membranes. Activated carbon has been added to ultrafiltration systems in order both to remove the organics that cause early clogging of the filter and to sorb many compounds that would pass through the filter. The activated carbon concentration should be less than 600 mg/L for the best operational efficiency. Powdered activated carbon (PAC) is usually used in conjunction with ultrafiltration membranes because the smaller particle sizes of the PAC have considerably faster adsorption kinetics and reduce the required contact time. As with all activated carbons, the carbon concentration required to achieve a particular effluent concentration is directly related to initial concentration of the contaminant in question (Adham, *et al.* 1991).

Limitations of Activated Carbon

Activated carbon cannot desorb high boiling solvents and will polymerize or oxidize some solvents to toxic or insoluble compounds (Blocki 1993). It has a very small net surface charge and is ineffective at removing free or hydrated metal ions, unless they are complexed with easily-adsorbed organics prior to filtration. However, once they are complexed with these insoluble organics, the complexed metals are readily adsorbed onto the carbon, which result in the desired high removal rates (Anderson and Rubin 1981).

Peat Moss

Peat is loosely defined as partially decomposed organic material, excluding coal, which is formed from dead plant remains in water in the absence of air. The physical structure and chemical composition of peat is determined by the types of plants (mosses, sedges and other wetland plants) from which it is formed. Peat is physically and chemically complex and is highly organic with its main components being humic and fulvic acids and cellulose.

Peatland development is controlled by several processes, including peat accumulation, *Sphagnum* acidification, and climate. The general movement from rich to poor fen and then to bog is primarily a result of peat accumulation. Peatland development can range from <1500 years to >2000 years and usually occurs in areas with gentle topography and where the prevailing climate has short, warm, moist summers and long, cold winters. Bogs and poor fens are *Sphagnum*-dominated while rich fens contain mostly brown mosses (Kuhry*, et al.* 1993).

Peat accumulation causes the land surface to become separated from the mineral-rich ground water, i.e., the depth to the water table increases. Mesotrophic rich fens develop into oligotrophic poor fens that are further acidified by *Sphagnum*. Continued peat accumulation results in the development of ombrotrophic bogs, which depend exclusively on precipitation for nutrients and water. The rapid transition from rich fen (pH > 6) to poor fen and bog (pH < 5) is most probably a result of chemical factors, *i.e.*, the 5 - 6 pH transition range is also where the bicarbonate alkalinity becomes zero. Once this bicarbonate buffer is gone, the peatland is very sensitive to further oligotrophication and *Sphagnum* acidification. The removal of regular contact with the deeper, mineral-rich ground water also reduces the opportunity for neutralization of the acidification caused by *Sphagnum* (Kuhry*, et al.* 1993).

Peat Composition

Peat contains the products of inhibited plant and vegetable matter decomposition and may contain up to 15% bituminous substances, including a wide range of saponifiable (*e.g.*, C_{18}-C_{30} free fatty acids, fatty acid triglycerides, and non-glyceride esters) and unsaponifiable liquids (*e.g.*, long-chain hydrocarbons, alcohols, and steroids). At ambient temperature, the peat bitumen is a solid-liquid system. The solid phase consists of several different crystalline species of carboxylic acids and esters while the liquid phase is highly viscous and consists of a mixture of paraffins, carboxylic acids, alcohols, and esters. The flow behavior of the bitumen is similar to that of a yield pseudoplastic fluid. The behavior is extremely temperature sensitive because of both the melting and crystallizing of the crystalline minerals and the changing polar interactions in the non-crystalline component. At ambient temperature using polarized light microscopy, the bitumen was found to contain many small crystallites (diameter, 5.4 μm). Using successive organic extraction steps, the peat bitumen was found to contain wax (43.9%), resin (37.9%), and asphaltene (6.7%) with the remaining 11.5% containing some visible peat fibers but probably consisting mostly of polymerized peat fatty acids and hydroxy acids. Infrared spectroscopy indicated that the polar species such as esters and acids are primarily in the wax and asphaltene fractions, while the resins consist largely of non-polar constituents (Leahy and Birkinshaw 1992).

Carboxylic acids and esters in the wax fraction likely are the dominating rheological influence in the bitumen. They affect the peat's physical behavior because they crystallize at a low temperature and mechanically hinder flow, and because their secondary bonding increases the liquid's viscosity. The crystallizing species appear to be the esters of the fatty acids rather than the more polar acids, possessing molecular weights below 1200 (Leahy and Birkinshaw 1992).

While the wax consists primarily of medium and high molecular weight species, the liquid resin is almost completely low molecular weight material, such as paraffinic liquids, and carbonyl and hydroxyl species. No aromatic or unsaturated species appear to be in the resin. The paraffinic liquids are non-crystalline, with flow characteristics, at ambient temperature, of a low-viscosity Newtonian fluid. As the crystallinity of the resin increases, the flow becomes yield pseudoplastic (Leahy and Birkinshaw 1992).

The asphaltene fraction appears to consist of similar-sized species to those in both the wax and the resin but is believed to contain more polar constituents. The crystallizing species in the asphaltene are of relatively high molecular weight; however, analysis of the asphaltene indicates that low molecular weight species are present and dilute the crystallizing species. The first fraction of the asphaltene on an infrared spectra is a paraffin, followed by mixtures of saturated acids and esters, with esters. Acids increase in significance and concentration in the later fractions. The largest-sized fractions of the asphaltene appear to contain several unsaturated compounds (Leahy and Birkinshaw 1992).

Hydraulic Characteristics

Peat moss (*sphagnum* moss) is a fibrous ("fibric") peat and is typically brown and/or yellow in color. It has easily identifiable undecomposed fibrous organic materials, and its bulk density is generally less than 0.1 g/cc. Because of its highly porous structure, peat moss can have a high hydraulic conductivity, up to 140 cm/hr. (Galli 1990). Its chemical and physical structure (pore volume of 80-90% [Karamanev, *et al.* 1994]) encourages water retention, and it can contain up to approximately 90% water by weight (Leahy and Birkinshaw 1992). Peat permeability varies greatly and is determined both by its degree of decomposition and the plants from which it came. A 50% change in a peat's moisture content can change its permeability up to five orders of magnitude (Mitchell and McDonald 1992). Generally, the more decomposed the peat is, the lower its hydraulic conductivity. Peats lose most of their hydraulic conductivity when compressed. Two different flow regimes exist in peat filters because of the peat's three-level, fractal-like structure, *i.e.*, the same shape of the structure is observed at three different magnifications. At low velocities, the liquid flows through the peat moss particles; however, at high velocities (above the critical velocity of approximately 0.1 cm/s), the liquid mainly flows between the solid aggregates with only a small amount penetrating the particles forming the aggregates. The mass transfer mechanisms appear to be due to the following: 1) diffusional transfer at the smallest level; 2) convective or diffusional transfer (or both) at the second level, depending on the liquid velocity; and 3) convective transfer at the largest level (Karamanev, *et al.* 1994).

Peat moss' coarse structure likely causes the observed decrease in hydraulic conductivity as the water content is reduced. Peat also exhibits a hysteresis between the drying and wetting curves, likely because as the material dries out it becomes more hydrophobic and, consequently, more difficult to rewet (da Silva, *et al.* 1993), with severely dried peats (>= 35% moisture loss) being exceptionally difficult to rewet. Possible reasons for this phenomenon include macropore collapse and high micropore suction-pressures. Drying also shrinks humic molecules, binding the color-producing, lower-molecular-weight fractions together. The peat initially will repel new water; however, continuous rewetting eventually will lead to water penetrating all pore spaces, saturating the peat, and flushing out any accumulated color-producing organic acids (Mitchell and McDonald 1992).

Natural peaty clays have a high organic content (>20%) and are compressible because of void volume in the mix. However, amendment of the peat with sand can greatly reduce its compressibility, which also will increase its bulk density and decrease its moisture content. When the sand to peat ratio is 1.76, the bulk density of the mixture increases from 1,310 kg/m^3 to 1,776 kg/m^3, and the moisture content decreases from >80% to 23% (Lo, *et al.* 1990).

Organic Removal Capability

Peats can extract substantial amounts of either free-phase or dissolved hydrocarbons from water (between 50 and 90% of the starting wet volume and 63 and 97% of dissolved hydrocarbons from saturated solutions). In general, the best peats for hydrocarbon adsorption are low in fiber and birefringent organics and high in ash and guaiacyl lignin pyrolysis products. Because these parameters indicate the degree of peat decomposition, adsorption appears to increase as decomposition increases, possibly for the following reasons: (1) greater surface areas are associated with smaller particles; (2) chemical changes resulting from decomposition; or (3) inherent chemical or physical differences in the source plants. Sorption possibly results from the aromatic surfaces attracting the hydrocarbon while cross-linking side chains "trap it" and hold it in place. Another potential explanation of hydrocarbon sorption to peat is that the intermolecular distances and area within the lignocellulosic polymer are suitable for absorption between basal lignin units. Inter- and intra-molecular forces between the lignin and the hydrocarbon control the competition between the two mechanisms (Cohen, *et al.* 1991).

Toluene is sorbed more slowly to peat than either benzene or *m*-xylene, yet toluene had much less variation in its sorption to different peat types than benzene and *m*-xylene. With sufficient contact time, toluene sorption capacity is similar to that of benzene and *m*-xylene. In free-phase experiments, the absorbencies exhibited by the specific peat types did not depend on the type of hydrocarbon sorbed, with the Maine *sphagnum* peat having somewhat less absorption per unit volume than other peats. This may be a result of the visibly larger pore size in *Sphagnum* peat compared to other peats. *Sphagnum* has more visible, preserved fibers, a higher water-holding capacity, and a relatively high porosity, which, along with pore size, type, and shape, may be significant factors in hydrocarbon adsorbency (Cohen, *et al.* 1991).

Peat moss can, however, shrink or swell in the presence of some organic compounds, possibly because sorption site availability increases in liquid sulfoxides, with the increase being dependent on humification despite the general decrease in oxygen/carbon ratio with humification. Swelling and/or shrinkage of the peat has been demonstrated by sorption of pure (>95%) methyl, tetramethylene, and propyl sulfoxides and propyl sulfones on dewaxed, acid-form peats. Apparently, the cellulose particles adhere to one another when dry. The addition of a liquid, even a nonswelling one, lubricates the particles so that initially they compact slightly (Lyon 1995).

Alcohol sorption curves are similar, even with large differences in humification between the two peats studied, implying that the alcohol sorption sites within peats are not changed significantly by humification. Significant swelling was observed for peats immersed in propyl sulfoxide, demonstrating that the approximate limit of swelling, as found by Lyon and Rhodes, by solvents with molar volumes $\leq$ ca. 93 cm^3 mol^{-1}, can be exceeded when the liquid contains a strongly interacting functional group. The swelling limit for most alcohols is probably influenced more by the peat's basic sites rather than the acidic sites, and, therefore, different limits are possible for acidic and basic organic liquids (Lyon 1995).

The binding of polycyclic aromatic hydrocarbons (PAHs) to both solid soil humic materials and dissolved humic substances appears to be controlled by both adsorption and partitioning with the filter media, with the partitioning term being the most important for largely nonpolar sorbates. The sorption of phenols and PAHs correlates well with their hydrophobicity. The sorption of nonpolar organics correlates well with the oxygen content of the organic matter in the peat, with the exception of a few polymers that have a high oxygen content. Nitro and hydroxyl groups on a sorbate molecule tend to strengthen the molecule's sorption because of the charge transfer interactions that occur between the sorbate and the peat. The correlation between a nonpolar organic's hydrophobicity and sorption capacity is not valid for aromatic amines where sorption exceeds the estimated bonding by five to ten times. The number of aromatic rings also appears to influence sorption capacity significantly. Fulvic acids are slightly more polar than humic acids, and, thus, they are slightly more water soluble and have slightly different sorption capabilities (Kopinke, *et al.* 1995).

Peat can also leach organic compounds, especially colored organic matter such as humic and fulvic acids. The amount of leaching of colored compounds is dependent upon season (for an outdoor filter) and soil moisture. One possible explanation for the correlation of peat moisture and color distribution and intensity is the change in pH and water content during filtration. The peat showed a rapid initial rise in color and pH/acidity, followed by a gradual decline. The length of drying between filtration events indicates the size of the "store" of water-soluble, color-producing organic acids, especially in the top 3 cm where aerobic decomposition and oxidation also is occurring. When the filter is initially wetted, this "store" is released, and the effluent becomes colored as the decomposition products come into contact with water and become 'color' (Mitchell and McDonald 1992).

Inorganic (Non-Metal) Removal Capability

A peat-filter system has been developed for enhanced nitrogen removal or transformation in sanitary wastewater. The filter uses a layer of *sphagnum* peat moss placed below the weeping tile bed where nitrogen is assimilated into the fungal biomass, thus reducing the nitrogen content of the wastewater. Sixty to 100 percent removals have been achieved for nitrate levels up to 125 mg N/L (Robertson and Cherry 1995). Peat is an excellent substrate for microbial growth, with large colonies of nitrifying and denitrifying bacteria typically present. It can assimilate nutrients and organic wastes because of its high C:N:P ratio, which often approaches 100:10:1. Long-term phosphorus retention in peat is related to its calcium, aluminum, iron, and ash content with the higher the content of each of the above constituents, the higher the retention capability (Galli 1990). A peat filter system for treating septic tank effluent has been able to treat wastewater at a hydraulic loading rate of 40 L/m^2 of filter surface while maintaining a high effluent quality: NO_3-N (<5 mg/L), NH_3-N (0 - 17 mg/L), organic-N (0 - 7 mg/L), BOD_5 (5 - 20 mg/L), DO (3 - 13.3 mg/L), TSS (5 - 15 mg/L), pH (5.3 - 6.5), and fecal coliforms (reduced by 99.99+ %). The major drawback to the system was the tea color of the effluent (Daigle 1993).

Metal Removal Capability

Because of the lignins, cellulose, and humic and fulvic acids in peat, peat is highly colloidal, is polar, has a high cation-exchange capacity, and has a high specific adsorption capacity for transition metals and polar organics (Galli 1990). *Sphagnum* moss contains an anionic polysaccharide ('sphagnan') that selectively binds calcium and other multivalent metal cations. As the dead moss slowly becomes peat, soluble sphagnan is gradually released. However, sphagnan is unstable, and in the mildly acidic conditions of peatland formation, it is slowly converted into humus or humic acid. Humic acid also binds multivalent metal cations, and its selectivity for Ca^{2+} is even higher than that of sphagnan, thus ensuring that peatlands are permanently decalcified (Painter 1991).

Peat moss has been used to treat metal-bearing industrial effluents since it will adsorb, complex, or exchange various metal cations (Gosset, *et al.* 1986). Peat has an excellent natural capacity for ion exchange with copper, zinc, lead, and mercury, especially at pH levels between 3.0 and 8.5. The peat contains polar functional groups such as alcohols, aldehydes, ketones, acids, and phenolic residues which chemically bind metal ions from a solution (Sharma and Forster 1993). However, the sorption capacity of peat is finite and reversible and is controlled by the pH of the solution (Galli 1990).

Immobilization of a metal by peat depends on (i) the metal ion capture chemistry, (ii) solute transport rates from the bulk solution to the adsorbent surface, and (iii) the transport rates and equilibria within the adsorbent's interstices. For metal adsorption on peat, film diffusion appears to be the rate-controlling step; although at small peat-to-metal ratios, internal mass transfer also greatly influences the sorption. A three-step model can be used to describe the metal immobilization process by peat: (i) solute mass transfer from the solution to the particle surface, (ii) ion-exchange reactions at fixed sites on the peat, and (iii) internal diffusion of solute. In general, the ion-exchange reaction is very fast compared to the other two steps and is not the kinetic rate-limiting step. At high peat concentrations, film and external mass transfers are most important while at low peat concentrations, intraparticle diffusion controls the reaction rate (Allen, *et al.* 1992).

In buffered solutions, the order of sorption for four metal ions to peat is $Ni^{2+} > Cu^{2+} > Cd^{2+} = Zn^{2+}$, independent of peat origin. Above pH 3, copper binding is similar to nickel and is dependent upon the pH of the solution; cadmium and zinc present a similar pH dependence but are less strongly bound than the copper and nickel. Only the nickel cation, however, is bound strongly enough not to be desorbed when the pH is dropped to below 1.5 (Sharma and Forster 1993).

In unbuffered solutions, the pH drops between 0.2 and 0.6 pH units during filtration for all metal-peat combinations tested (Gosset, *et al.* 1986) because of the release of humic and fulvic acids during adsorption or ion exchange (Sharma and Foster 1993). Unsieved and non-acidified oligotrophic or eutrophic peat samples seem to bind copper more rapidly and efficiently than sieved and acidified ones, possibly because the structure of the peat is changed during acid pretreatment. The sorption curves for the metals are not linear, regardless of the peat-metal combination, indicating that the peat-metal complex stoichiometry and thermodynamics are probably dependent both on the free metal concentration and on pH, which varies in unbuffered solutions. Although saturation limits of 200 mmol metal/kg dry weight peat were observed in buffered solution, sorption saturation (even at 0.1 M metal in 50 g/L peat) was not observed in unbuffered solutions. Maximum removal could be achieved when the metal concentration in the buffered solution was in the 0.1 - 1 mM range, provided that there is adequate contact time (Gosset, *et al.* 1986). *Sphagnum* moss has been shown to remove iron (75% reduction) and manganese (25%) from acid mine drainage in Pennsylvania ("Moss Tested to Remove Manganese from Mine Drainage," 1984).

Sphagnum moss peat concentrations ranging from 4 to 40 g/L can effectively remove hexavalent chromium from solution (10 to 1000 mg/L Cr(VI)), especially when the ion concentrations are low. At equilibrium pH of 2.0, almost complete removal of Cr(VI) can be achieved when chromium concentrations are less than 100 mg/L, while at equilibrium pH of 1.5, 64% Cr(VI) removal can be achieved when chromium concentrations are less than 1000 mg/L. The sorption is pH dependent, with the optimum range being 1.5-3, and is controlled by (i) chemical reduction, *i.e.*, Cr(VI) to Cr(III); and (ii) adsorption of the mainly Cr(VI) species. The chromium is strongly bound, and little desorption occurs in low molarity caustic solutions. In high molarity caustic solutions, the peat itself 'disintegrates' (Sharma and Forster 1993).

Limitations of Peat Filters

The release of color upon wetting is one problem with peat. Another potential problem is that peat may leach some nutrients, depending on the soil and water chemistry and water level. *Sphagnum* peat generally will release significantly more phosphorus and ammonium than *Carex* peat with the water quality determining the extent of nutrient release, especially in waters with a high sulfate concentration. Temperature also influences the amount of ammonium, potassium, and phosphate leached. Nutrient leaching will increase two to three fold after the peat has been frozen (Koerlsman, *et al.* 1993).

Stormwater Runoff Treatment

Urban road runoff generally has large concentrations of heavy metals and particulate organic carbon, as well as high alkalinity. Peat moss has been used as a growth medium for plants, such as red maple and cranberry seedlings, to treat urban stormwater runoff containing lead and zinc. In general, metals in acidic swampwater were more available to the plants than those in alkaline runoff and uptake of the metals usually increased with decreasing pH and decreased with increasing soil organic matter content. However, soluble organic acids can mobilize heavy metals into solution, even those in alkaline runoff water (Vedagiri and Ehrenfeld 1991).

Peat-sand filters (PSF) have been proposed to treat urban runoff. The PSF is an aerobic, "man-made" filtration system, unlike older sand or peat filtration systems that use naturally occurring soils as the filter. The peat-sand mixture layer must be manufactured, as it does not occur in nature. A PSF can be expected to remove most of the phosphorus, BOD, and pathogens, and with a good grass cover, other nutrients (Galli 1990).

The Peat-Sand Filter System designed by the Metropolitan Washington Council of Governments (Washington, D.C.) would have a good grass cover on top underlain by 12 to 18 inches of peat. The peat layer is supported by a 4-inch mixture of sand and peat that is supported by a 20- to 24-inch layer of fine to medium grain sand. Under the sand are gravel and the drainage pipe. The mixture layer is needed because it will provide the necessary continuous contact between the peat and the sand layers and ensure uniform water flow. Because the PSF is a biological filtration system, it will work best during the growing season when the grass cover can provide the additional nutrient removal that will not occur in the rest of the filter (Galli 1990). The expected pollutant removal efficiencies are given in Table 14.

Table 14. Peat-sand filter pollutant removal efficiencies (Source: Galli 1990)

Pollutant	Removal Efficiency (%)
Suspended Solids	90
Total Phosphorus	70
Total Nitrogen	50
BOD	90
Trace Metals	80
Bacteria	90

Compost

Composts made from yard waste, primarily leaves, have been found to have a very high capacity for adsorbing heavy metals, oils, greases, nutrients, and organic toxins due to the humic content of the compost. These humic compounds are stable, insoluble, and have a high molecular weight. They act like polyelectrolytes and remove the toxicants from the runoff either by adsorption or ion-exchange. The exact content of and aging process for the composts used by W&H Pacific/CSF Systems, Inc. are not public knowledge with the result that the filter installation-and-maintenance company supplies the compost to the stormwater treatment device owner.

The composted leaf filter was developed by W&H Pacific for Washington County (WA), the Unified Sewer Agency, and the Metropolitan Service District of Washington County (W&H Pacific 1992a). The filter consists of a bottom impermeable membrane with a drainage layer above it. Above the drainage layer is a geotextile fabric upon which rests the compost material. The actual toxicant removal occurs in the compost layer by filtration, adsorption, ion exchange, or biodegradation, or by a combination of these processes.

The composted leaf filter is advertised as an improvement over other stormwater treatment devices, such as detention ponds and grass swales, because the square footage required for the filter is much smaller than for the other devices. A small presettling area (less than one minute detention time) is recommended; otherwise, the larger particles and floatables will prematurely clog the filter and reduce its treatment efficiency. Filter design was based on permeability tests performed by W&H Pacific and the design flow was selected as 2.25 gallons per minute (0.30 m^3/min), which gives a required compost bed surface area of 200 ft^2/cfs (60,435 m^2/m^3/sec.). The results from the testing of a prototype Compost Storm Water Filter System (CSF) are given in Table 15. This filter was located where the drainage area is 74 acres (3.9 acres highway, 70 acres mixed residential).

A three-year testing program on the CSF has shown that the filter is excellent at removing metals and hydrocarbons from the runoff. Sediment accumulation, always a potential problem for any filtering system, was, during the 1992-93 testing season, approximately 74 ft^3 (2.1 m^3) with an average thickness range of 0.25 to 1.27 ft (0.07 to 0.4 m). During the 1993-94 season, 111 ft^3 (3.1 m^3) of sediment with an average thickness of 0.5 to 1.2 ft (0.14 to 0.4 m) collected in the system (CSF Systems 1994). Based upon the sample results at the location of the compost filter, the first flush of a storm had the heaviest pollutant loadings, and the filter had the highest removal efficiencies during this first flush. This indicates that the CSF System is capable of treating a shock loading of pollutants while producing an acceptable effluent. The average first flush removal rates for the three years of operation are given below in Table 16.

CSF Systems, Inc., the manufacturer and distributor of the compost filter, outlines the advantages and disadvantages of this compost system. One advantage is that the filter has a very high buffering capacity in the alkaline range. When the influent is between pH 6.7 and 8.3, the effluent is consistently between pH 7.0 and 8.0. However, because the media acts as an ion-exchange resin, whenever a pollutant sorbs to the media, an ion is 'leached off.' In the case of the compost, soluble phosphorus is one of the ions that is leached off during ion exchange (influent, 0.09 - 1.0 mg/L; effluent, 0.29 mg/L). Soluble phosphorus likely is released from the captured solids through microbial action and since the compost only has a weak anion exchange capacity, most of the soluble phosphorus is not removed from the water once it is leached from the compost. Testing has also shown an increase in boron and nitrate in the effluent of the compost filter (CSF Systems 1994).

Table 15. Compost filter pollutant removal efficiencies (Source: CSF Systems 1994)

Pollutant	Influent/Effluent Concentration Range	Removal Rate (%)
Turbidity		82
Total Solids		49
Suspended Solids		92
Total Volatile Suspended Solids	0-90 mg/L Influent; 0-14 mg/L Effluent	89
COD		70
Settleable Solids	0-4 mL/L Influent; 0.05-0.1 mL/L Effluent	95
Total Phosphorus		49
Ammonia		60
Total Kjeldahl Nitrogen		57
Copper		7
Zinc		83
Lead		83
Aluminum		84
Iron		91
Petroleum Hydrocarbons		84
Oil and Grease		81

Table 16. Compost filter removal efficiencies – first flush (Source: W&H Pacific 1992b; CSF Systems 1994)

Pollutant	Removal Rate (%)
Turbidity	86
Total Solids	63
Total Suspended Solids	94
Settleable Solids	98
Total Volatile Suspended Solids	97(*)
COD	79
Total Phosphorus	63
Ammonia	65
Total Kjeldahl Nitrogen	72
Copper	83
Zinc	86
Lead	86
Aluminum	88
Iron	93

* Results are from the first year of operation only.

Zeolite

Adsorbents must be sufficiently selective and have adequate capacity and stability to achieve the required separation economically over a prolonged period of time. To get the required capacity, the adsorbent must have a high specific surface area, *i.e.*, be highly porous with fine pores (micropores). Furthermore, most important adsorbents use physical adsorption (multilayer) rather than chemisorption in which the capacity is limited to monolayer coverage (Ruthven 1988). Zeolites are preferred as adsorbents in the chemical process industry because they are inorganic, non-flammable, and can withstand very high temperatures (Vaughn 1988). Generally, they are porous aluminasilicates which may occur naturally but also can be synthesized (Blocki 1993). They have been used in such diverse applications as natural gas purification (chabazite), radioactive waste disposal (clinoptilolite), ammonia recovery from sewage effluents (clinoptilolite), and various petroleum and petrochemical catalyst applications (erionite, mordenite) (Vaughn 1988).

Physical Characteristics

Zeolites occur naturally in basaltic lava, in specific rocks subjected to moderate geologic temperature and pressure, and in altered and reacted volcanic ash deposits (Vaughn 1988). Clinoptilolite is the most abundant naturally occurring zeolite. The formula of one cell of clinoptilolite is $(Ca,Na_2,K_2)_3[Al_6Si_{30}O_{72}]\cdot 24\ H_2O$. It has a two-dimensional 8-ring and 10-ring channel structure with the largest cavity measuring 4.4 x 7.2 Å. Zeolite surface chemistry is similar to that of smectite clays with the difference between the two being that natural zeolites may be millimeter or greater sized particles and do not exhibit shrink-swell behavior (Haggerty and Bowman 1994).

The primary building block of zeolite is a tetrahedron of four oxygen atoms surrounding a central silicon atom $(SiO_4)^{4-}$. Zeolite polyhedra are connected by shared oxygen atoms on the corners, and these polyhedra connect to form the various specific zeolite crystal structures. Different combinations or arrangements of the same polyhedra may give numerous distinctive zeolites. Other elements, such as Al, Ga, Ge and Fe (Haggerty and Bowman 1994), may be substituted for the silicon, provided that they "fit" into the center of the four tetrahedral oxygen atoms without too much strain on the oxygen bonds and that the resultant structure is electrically neutral (Vaughn 1988). Union Carbide scientists in aluminophosphate chemistry recently have expanded zeolite compositions to include about 13 elements, including Li, Be, B, Mg, Co, Mn, Zn, P, As, and Ti (Haggerty and Bowman 1994). These variations in the chemistry in the basic structure change the pore sizes available for sorption and therefore alter the selectivity that can be achieved by a zeolite (Blocki 1993).

Zeolites often are called molecular sieves because their crystalline framework has channels (pores) and interconnecting voids of molecular size (3 to 10 Å) (Vaughn 1988). Zeolite species are often specified by letters after their name. Zeolite A has 8-member oxygen rings with a void size of 4.3 Å in the Ca^{2+} form, 3.8 Å in the Na^+ form and 3.0 Å in the K^+ form. X and Y zeolite pores, both of which have 12-member oxygen rings and whose frameworks are identical, are larger, having a free aperture of about 8.1 Å. The difference between the X and Y zeolite is the Si/Al ratio which controls the cation density and therefore affects its adsorptive properties. The zeolite with the intermediate pore size has a 10-member oxygen ring and has a pore size of about 6.0 Å (Ruthven 1988). The ability to control access to the reactive sites by selecting the zeolite with the pore size in the desired range, as well as the size and stereochemistry of the site itself, makes molecular-level control of chemical reactions possible (Vaughn 1988).

Zeolite Synthesis

Zeolite synthesis is usually a batch process run at one of the following conditions: (1) 90-100°C, 1 atm. pressure, $pH > 10$; (2) 140-180°C, 5 - 10 atm., $pH > 10$; or (3) 100-180°C, water + "amine" autogenous pressure, $pH > 10$. The metal phosphates, a relatively new class of zeolites, are made under conditions similar to (3) above, except that the pH is between 3 and 6 (Vaughn 1988). By varying the chemistry in the basic structure, different pore sizes and different selectivities can be achieved (Blocki 1993).

Once the crystal synthesis is complete, the zeolite is mixed with a binder, and then formed into beads, pills, tablets, or extrudates. In most applications, the binder must be completely inert to avoid side reactions. Fabrication of the zeolite pellet is difficult because one must avoid plugging the pores with the binder and must avoid crushing the crystalline structure in high-pressure pilling processes. Most applications require maximum activity or sorption capacity, and, therefore, the manufacturing process tries to maximize zeolite content and minimize binder content (Vaughn 1988).

Zeolite Adsorption/Ion-Exchange Characteristics

Because micropore size is uniform in zeolites, these adsorbents have a rather sharp cut-off of sorption with increasing molecular size. Although the framework primarily determines the pore size, the free aperture, particularly in the smaller 8-ring sieves, may be modified by ion exchange, again tailoring the zeolite to a specific effective pore size. Zeolite also is a polar molecule, and it has some unique affinities that are promoted by the ability to fit a particular molecular shape into a pore. These features also contribute to the ability of zeolite to be a highly selective adsorbent. Adsorption forces for zeolites can be divided into van der Waals forces, induced dipole interactions, and other electrostatic forces (polarization, dipole and quadrupole interactions). Van der Waals forces affect any sorbate-sorbent pair because they depend on the surface (micropore) geometry and increase with the polarizability of the sorbate molecule. Molecules which just 'fit' in the pore channel have maximum van der Waals interaction energy. By contrast, electrostatic forces, except for polarization energy, require both a surface electric field, *i.e.*, polar or heterogeneous adsorbent, and a dipolar or quadrupolar sorbate molecule (Ruthven 1988).

When Al^{3+} is substituted for Si^{4+} in the zeolite framework, a net negative charge on the molecule results. This is compensated for by a 'nonframework' cation (*e.g.*, Na^+), which is 'held' in the pores of the structure. Because this cation is not a part of the crystalline lattice, it is relatively mobile and easily exchangeable for other cations (Vaughn 1988). Ion-exchange and adsorption processes for zeolites often are even more complicated than for organic ion-exchange resins because the zeolite has two distinct pore structures: micropores in the crystals and macropores in the binder, both of which can participate in sorption (Robinson, *et al.* 1994). Zeolites have internal and external surface areas of up to several hundred meters squared per gram. They can have cation-exchange capacities (CECs) of up to several equivalents per kilogram (Haggerty and Bowman 1994).

Because of the exchangeable cations, zeolites are polar adsorbents. Molecules such as water or ammonia (high dipole), CO_2, N_2 (quadrupolar) or aromatic hydrocarbons (π layer interaction) therefore adsorb more strongly than nonpolar compounds of similar molecular weight. This affinity generally increases with increasing charge on the exchangeable cation and decreasing cation radius, but its effect may be masked by water, which, because it is strongly bound to a zeolite, will reduce the zeolite's affinity for other, less polar molecules. Aqueous sorption has considerable amounts of water present in the intracrystalline fluid (Ruthven 1988).

Although most zeolites are strongly hydrophilic (because the strongly polar water molecule interacts with the cation), the zeolites with a high silica content (nonpolar surfaces) are actually hydrophobic because water is adsorbed less strongly than most organics. The adsorption is limited to van der Waals forces, and water is adsorbed less strongly than the more polarizable organics (Ruthven 1988). The hydrophilic zeolites may not separate volatile organic compounds (VOCs) well in a humid atmosphere, where complete drying may not occur between sorption events (Blocki 1993).

Liquid and concentration-dependent surface diffusion both contribute to macropore diffusion (Robinson, *et al.* 1994). Diffusivities (at 600 K) range from 10^{-6} - 10^{-7} cm^2/s for benzene and p-xylene to 10^{-14} - 10^{-15} cm^2/s for hexamethylbenzene and anthracene. Although diffusivity changes cannot be correlated directly to molecular weight, molecular length, or critical molecular diameter sequence, the diffusivities generally tend to decrease with increasing sorbate size. Diffusivity instead correlates well with the sorbate's moment of inertia, suggesting that restrictions of the rotational freedom of the sorbate molecule affects diffusivity. This pattern indicates that the diffusion of sterically hindered planar molecules within the pores of a zeolite is controlled primarily by entropy effects, not because the pore size is too small. Therefore, a sharp cutoff of sorbate size exists and, for molecules larger than the cutoff and whose deformation is sterically hindered, essentially no intracrystalline pore penetration and sorption exist (Ruthven and Kaul 1993b).

Organic Removal Capability

Hydrophobic zeolites generally are non-flammable, temperature-resistant (up to 1000°C), inert to many polar and nonpolar solvents, and are efficient adsorbents for a wide concentration range (Blocki 1993). The saturation capacity is expected to be one molecule per pore, and the adsorption isotherms for many higher weight aromatic hydrocarbons, such as benzene, toluene, xylene, mesitylene, tetramethylbenzene, naphthalene, hexamethylbenzene, dimethylnaphthalene, and anthracene, approach this saturation capacity. There is very little difference between either the isotherms or heats of sorption for different aromatic sorbates with the same carbon number. Therefore, for sufficiently large molecules, steric restrictions of the pores reduce the contact between neighboring molecules and, therefore, their potential for interaction that would prevent sorption (Ruthven and Kaul 1993a).

The higher molecular weight aromatics are very strongly adsorbed, and intracrystalline diffusion is quite slow and temperature dependent. The sorption capacity, however, is essentially independent of temperature, reflecting the tendency of the larger molecules to average out the effect of adsorbent heterogeneities (Ruthven and Kaul 1993a). Zeolites can also sorb unsaturated hydrocarbons with the sorption 'strength' pattern as follows: aromatics > olefins > paraffins (Ruthven 1988). However, unlike activated carbon with its variety of pore sizes, hydrophobic zeolite is slower at separating some relatively common solvents such as xylene because the solvent molecules' diameters are less than the hydrophobic zeolite's pore sizes (Blocki 1993).

Modifying the surface of a zeolite by initially performing ion-exchange with a cationic surfactant can increase the sorption capacity for organics that do not sorb well to natural zeolite. Quarternary amine (HDTMA)-modified zeolites can remove chlorinated aliphatic compounds and benzene derivatives from aqueous solution by a partitioning-like mechanism without lowering the zeolite's naturally high-sorption affinity for transition metal cations such as lead (Eyde 1993; Haggerty and Bowman 1994).

Inorganic Removal Capability

Because of its net negative charge, natural zeolite does not sorb anions well, if at all (Eyde 1993). Surface modification, such as ion-exchange with cationic surfactants, has improved the ability of zeolite to sorb anions and other compounds that natural zeolite did not sorb well. These sorbed cationic surfactants alter the surface charge of the zeolite, thus allowing it to sorb anions and other compounds of interest. Removal of inorganic oxyanions, such as chromate, selenate and sulfate from aqueous solutions improved from nearly zero sorption when a clinoptilolite-dominated zeolite was modified by 140 mmol/kg zeolite (15 meq/g) of hexadecyltrimethylammonium (HDTMA). Anion sorption was greatest when the HDTMA satisfied the zeolite's total external cation-exchange capacity. Anion retention (4 mmol/kg for CrO_4 and >2 mmol/kg for SeO_4 compared to 1 mmol/kg for both on natural, unmodified zeolite) resulted from the formation of an HDTMA-anion precipitate on the zeolite surface (Eyde 1993; Haggerty and Bowman 1994).

Some zeolites are unstable at low pH because the aluminum in the framework is hydrolyzed, and so one approach to exchanging transition metals at low pH is to first form ammonia complexes by dissolving them in dilute aqueous ammonium hydroxide and then carrying out the exchange at high pH (Vaughn 1988). The HDTMA-modified surface, however, is stable at low pH, higher ionic strength and with organic solvents (Eyde 1993; Haggerty and Bowman 1994). For the US Bureau of Mines, zeolites are an alternative to conventional precipitation removal techniques for metals such as lead (Eyde 1993).

Enretech

ENRETECH I is a light-weight, non-toxic, 100% cellulose product (waste from cotton milling) that can be used to clean up oil spills, especially in areas where it is difficult for people to transport themselves and their supplies to the spill and clean it up. It can also be used in areas such as tank storage sites, fueling locations, oil production fields, and oil field pipe treatment yards to collect slow leaks. ENRETECH I is also effective at cleaning up fuel, oil, paint, or coolant spills on highways (RAM Services, Inc. 1995). The ENRETECH I material has the consistency of blown-in fiberglass or mineral wool insulation.

Forest Products Agrofiber

The Forest Products Research Lab agrofiber product was developed as both an economic oil adsorbent and as an economic ion-exchange medium for pollutant removal from water. Kenaf and jute fibers, along with forest wastes such as barks and pine needles, have been found to efficiently remove copper from water. Chemical treatment of the kenaf with reactive yellow-2 significantly increased the adsorption capacity of the kenaf for copper (Forest Products Research Lab 1995).

Gunderboom and EMCON Filter Fabrics

The Gunderboom filter fabric is a woven textile that is marketed as a sorbent fabric for oil spill cleanups. The EMCON filter fabric is a woven fabric that was sold for use in stormwater treatment devices. Emcon North West in Bothell, WA developed it for use in existing storm sewer inlets. It is currently being marketed as the "Type I Catchbasin Filter" (Foss Environmental Services in Seattle, WA).

Limitations of the Literature Review

For most of the investigated media, very little information is available regarding their ability to remove pollutants from a mixed-component influent and what information is available may not be applicable to stormwater runoff treatment. This is because the work was performed using continuous filtration and/or the influent concentration was many times greater than the pollutant concentrations typically found in urban runoff. Complete information on design life and maintenance requirements is not available. This project was designed to supplement the available information about these filters. In particular, the project was designed in order to determine the life of a filter in the field and to investigate any potential maintenance problems. Testing was done on a laboratory-scale using actual stormwater runoff to address these issues. The following two chapters detail the results of the laboratory-scale tests. Future work will examine selected filter media at a pilot-scale.

Chapter 3
Methodology

Overview of the Experimental Design

The initial scope of this project was to determine the design variables for the sand filter that would polish the effluent from the settling chamber of the Multi-Chamber Treatment Train (MCTT), a stormwater runoff treatment device that has been designed by Dr. Robert Pitt at the University of Alabama at Birmingham (UAB) to treat the runoff from small, problem source areas, such as service stations and maintenance yards. The MCTT consists of three chambers, the sump (grit removal), the settling chamber, and the filter. This device is designed to be installed at the storm sewer inlet from a problem source area with the effluent from the device being directly discharged to the storm drain system. The appeal of this device to owners of small, problem source areas is that the device is low maintenance (1 - 2 times per year maximum) and low cost for construction and operation.

Based on the results from the Austin, TX, sand filters, the MCTT's initial design was to have a sand filter as the effluent polisher. The purpose of this project was to determine the optimum depth and grain size characteristics for this filter. A filtration column was constructed using the design guidelines from Austin (18" [46 cm] of sand on top of a gravel underlayer) in 1000 mL graduated Kimax burets (acquired from Fisher Scientific). The first tests evaluated the water retention in the column, steady state flow rate through the media and the quantity of solids that can be loaded on the column before 'clogging.' Mass balance analyses were then performed by filtering a sodium chloride solution (4 g/L) through the column followed by filtering repeated slugs of 18 MΩ resistivity water. These tests with NaCl determined the water retention and exchange of the material with repeated flushings. Stormwater runoff was then filtered, and grab samples were collected and analyzed for toxicity (Microtox™), turbidity, and conductivity. The results of all these tests indicated that the filter was not performing as expected based on the Austin results. Permanent retention of toxicants was not occurring in the column; instead, trapped toxicants were displaced from (flushed out of) the pores during subsequent tests.

Because of these results, this project was expanded to evaluate several prospective stormwater filtration media using the filter construction specifications from Austin. Since the physical straining in the sand filter was not effective at permanently retaining the toxicants, other media were selected based on their ability to remove pollutants of interest through chemical reactions, either adsorption or ion exchange. The filtration media used in the continuation of this research included the following: activated carbon, peat moss, zeolite, compost, Enretech (a cellulose waste), and a chemically-modified agrofiber. Sand was also used as a standard for comparison. These materials had a wide range of expected performances and included relatively expensive media known to provide excellent treatment (activated carbon) and waste materials (composted leaves, Enretech, and the agrofiber) with uncertain removal characteristics. Although their expected pollutant removal efficiencies were low (Agnew 1995), two filter fabrics were also selected for testing. One of the fabrics (EMCON fabric from BAMCON) was available commercially for stormwater treatment at the time of acquisition, and the other (Gunderboom) was being used in the MCTT at the Transportation Parking Lot at UAB to distribute water equally across the surface area of the filter. Past testing of the Gunderboom fabric found that water will not flow through the fabric until a two-to-three inch (5 to 7.5 cm) head had built up on it. Therefore, the Gunderboom can be used on top of a conventional filter to evenly distribute water across the filter surface and prevent bypassing of part of the filter (Pitt and Clark 1996).

The purpose of the revised research was to determine which filtration media provided the "best" removal for the pollutants of interest with the intention that this information be used by stormwater filter designers to determine the filter media that best suits their needs. A secondary purpose was to determine and describe potential drawbacks to the use of each of the media. A new testing program was designed, and the components of that program are listed below:

- sediment loading on media before clogging
- effects of pH and ionic strength on adsorption of pollutants
- long-term tests to measure chemical breakthrough

The formula needed to determine the number of samples given a predefined sample error is provided by Cameron and is as follows:

$$n = (Z_{1-\alpha} + Z_{1-\beta})^2\sigma^2/d^2$$

where n is the number of samples needed; Z is the area under the normal distribution at the locations ($1-\alpha$) and ($1-\beta$); σ^2 is the variance; and d is the number of units higher than the true mean that is acceptable. Using an alpha 0.05, a power of 90%, a d that is equal to twice the mean, and a coefficient of variation of 1, the number of samples required during each long-term performance evaluation is at least five. It was decided that six grab samples should be collected during the bench-scale tests because statistical significance for most parameters can be determined using the Wilcoxon signed-rank method to less than 0.01, yet the required number of laboratory analyses can be held to a reasonable level. Additional samples will be collected for the long-term performance tests if more runoff events occur during the testing time.

Experimental Procedure

Filtration Media and Test Apparatus

Because these experiments involved testing of the filtration media as they are used in the field, the columns were constructed according to the design guidelines provided by the City of Austin (1988) and Galli (1990), and were rinsed according to the rinsing directions supplied by CSF Systems, Inc. (1994). The filtration columns used in these experiments were Kimax-brand, one-liter, graduated burets (from Fisher Scientific) (inner diameter = 48 mm) or, for the filter fabrics, borosilicate glass (from Curtin Matheson Scientific) (inner diameter = 45 mm) cut to approximately the same length as the burets. The filtration media columns were constructed by first cutting a piece of fiberglass window screen, purchased at a local hardware store, into a 10 cm x 10 cm square. This screen was placed in the bottom of the buret and approximately five centimeters of epoxy-coated fish-tank gravel (from Wal-Mart) were poured on top of it to the 1000 mL mark. The column was then rinsed with one hundred milliliters of tap water.

Fifteen centimeters of sand were then added on top of the gravel, as recommended Galli (1990). The fifteen layer sand filter is added to the bottom of the column to ensure proper drainage in the lower section of the column. It is desirable to maintain aerobic conditions in the bottom of the filter for aerobic microbial activity. Otherwise, during field operations, a layer of water may collect in the bottom of the filter, turning that area anaerobic and causing release of previously retained pollutants. The sand was then rinsed at least twice, in one hundred milliliter increments, with tap water. After the sand layer had drained, approximately thirty centimeters of the media of interest (mixture 50/50 by volume of the sorption media and sand) were added to the column on top of the sand underlayer. After the medium of interest had been added, the filters were rinsed several times with tap water in accordance with the directions supplied by CSF Systems, Inc. for constructing the compost filter and then allowed to stand overnight before use as per their specifications. Since a sand filter was compared to the other media, the sand filter was constructed in a manner similar to the other filters. This includes a 15-cm sand bottom layer and a 30-cm sand layer on top of that, for a total of 45 centimeters of sand.

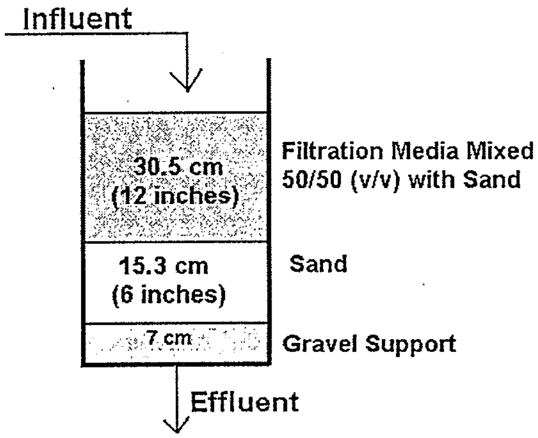

Figure 3.1 Column Construction

Filter fabric test columns were constructed by attaching a 15 cm x 15 cm piece of the fabric to the bottom of the glass tubes with stainless steel hose clamps that were purchased locally. The fabric and column were then set in a borosilicate glass funnel (from Fisher Scientific).

A carousel was constructed to hold all ten of the filtration columns needed for a single run. The carousel was made from painted plywood. The need for homogeneity of the influent dictated the use of a flow splitter. The flow splitter was designed to allow a single influent flow to be randomly split into a maximum of ten equal effluent flows. Delrin plastic was used to construct the splitter with the machining on the flow splitter done by MGM Machining in Helena, AL. Ten holes designed to accommodate ten one-half inch I.D. pipe-to-tube adapters or plugs were drilled into a six-inch cylinder of Delrin plastic at 45 degree angles and 36 degrees center to center. The holes were drilled so that they would converge at a sharp point in the center of the piece. The purpose of the sharp point was to remove a potential settling surface for any larger particles that may settle out of the runoff. The exterior bottom section was angled at approximately 45 degrees. A plexiglass support was constructed for the flow splitter so that the splitter was high enough to allow the runoff to flow down the tubes at a 45-degree angle from the base of the splitter. This 45-degree angle was assumed to be sufficient to prevent particle deposition on the insides of the tubes, even during low flow conditions.

In order to address the concern about leaching from the construction materials, all construction materials were leach-tested by soaking them in approximately 400 mL of 18 MΩ water for about 65 hours. The water was then tested for toxicity, turbidity, pH, conductivity, color, organics, pesticides, and heavy metals. Results of these tests showed that the use of the Delrin Plastic, Plexiglas, Black Plastic Fittings, and Reinforced PVC Tubing on the sections of the apparatus that came into contact with the stormwater runoff would be acceptable. The fiberglass window screen was found to be toxic to the Microtox™ luminescent bacteria when the screen was left to soak overnight. However, occasional rinsing of the screen did not add toxicity to the water.

The filtration media used in this project included the following: sand, activated carbon, peat moss, zeolite, compost, ENRETECH I, Forest Product agrofiber, Gunderboom filter fabric, and EMCON filter fabric. Because of the variability in the hydraulic conductivities and contact times of the adsorbent media alone, sand was mixed with all media (approximately half and half by volume), except the fabrics, before the mixed media was added to the filtration columns. In order to get a better "distribution" or "mixing" of media for the Enretech and Forest Products material, these materials were broken apart by hand (unclumped for the Enretech and torn apart for the Forest Products material) into small pieces.

The sand was purchased from Porter Warner Industries in Birmingham, AL, the supplier of sand for the wastewater treatment plants operated by Jefferson County, AL. The type of sand selected was the type that was closest in size distribution to that used in the Cahaba River Wastewater Treatment Plant in Hoover, AL. The sand used in these tests had a uniformity coefficient of approximately 1.45, with d_{10} = 0.31 mm and d_{60} = 0.45 mm. The ratio of column diameter to median filter grain particle size for the sand filter (the media used to determine filter height and column diameter) was greater than 100 which, according to other researchers, should be sufficient to avoid significant wall effects and to get the Reynolds number for flow through the filter to be greater than 20 (Clark, *et al.* 1992).

The activated carbon and zeolite were purchased from Aquatic Eco-Systems, Apopka, FL. The peat moss was a *sphagnum* moss sold by K-Mart in their garden supply area. The compost was a municipal leaf compost supplied by CSF Systems, Inc., in Portland, OR. According to CSF Systems, the compost was generated from only certain types of leaves in order to achieve the maximum adsorption capacity and, therefore, maximum pollutant removal from the stormwater of Portland, OR (John Knudsen, personal communication 1994). However, visual inspection of the compost received from them revealed pieces of glass, indicating that the selection process for the compost generated in mass quantities is not as particular as it was for the prototype devices. Because this compost is different than that used in the prototype, pollutant removal efficiencies likely are different than that described in the literature review. When selecting the compost to be used in the filter, no large pieces of twigs or glass were chosen.

The ENRETECH I material, supplied by RAM Services, Inc., Birmingham, AL, is a cellulose waste fiber from cotton milling with the consistency of blown-in fiberglass or mineral wool insulation. It was developed for cleaning up oil spills. The Forest Product was an agrofiber made from kenaf that is sandwiched between two fabric layers that have the texture of cobwebs. It was designed and is still being optimized for use in removing pollutants from water, especially stormwater. The Gunderboom was a filter fabric supplied by Amoco for use in oil spill cleanup. The EMCON fabric was supplied by Emcon North West (Bothell, WA) and is now sold by Foss Environmental Services Company (Seattle, WA). These two filter fabrics were selected from many that were tested for particle removal capability by particle size distribution analysis of their effluents. The Gunderboom was also selected because it is currently being used in the Multi-Chambered Treatment Train (MCTT) as described in the first volume of this research series (Pitt, *et al.* 1999).

Figure 3-3. Columns on Carousel

A peristaltic pump (from Cole Parmer Instruments) with Masterflex tubing was used to pump the sample either from a 200 L Nalgene drum (for the unpretreated runoff tests and bench-scale tests) or from the settling chamber of the MCTT (presettled runoff) to the splitting funnel where it was split into ten equal portions and dispensed to the ten columns on the carousel. Both grab samples and a composite sample were collected of the effluent samples from filtering unpretreated runoff. Grab samples were collected in clean 500 mL HDPE bottles that were pre-rinsed with distilled water. The composite samples were collected in Nalgene-brand, eight-liter polypropylene jugs (from Curtin Matheson Scientific). Grab samples from the bench-scale testing effluents were collected in clean 500 mL amber glass jars that were pre-rinsed with distilled water. Effluent samples from filtering presettled runoff in the MCTT were collected in clean, Nalgene-brand, eight-liter polypropylene jugs that were pre-rinsed with distilled water. After collection, the composite samples were immediately split into unfiltered and filtered fractions by filtering a portion of the well-mixed sample through 0.45 μm nominal pore size gel membrane filters (Gelman Metricel filters from Fisher Scientific). The sample portions, both filtered and unfiltered fractions, to be used in metals analysis were immediately preserved with 6 M nitric acid to a sample pH of less than 2. All other portions were then refrigerated at 4°C until analysis.

Collection of Stormwater Runoff

For all filtration tests, stormwater runoff had to be collected. For the preliminary investigations on the sand filter, the runoff used was a composite of runoff received from Stafford Township, NJ. The unpretreated runoff was a composite of runoffs collected from Stafford Township, NJ, the UAB Remote Parking Lot, the Ruby Avenue Public Works Garage in Milwaukee, WI, and a metal roof in Wilsonville, AL. Sheetflow runoff was collected in the settling chamber of the MCTT at UAB Fleet Services Operation and Remote Parking Lot at the corner of 8th Street South and 7th Avenue South, Birmingham, AL. Runoff from this location was used both for the bench-scale testing and for filtering the presettled runoff. The location on the UAB campus was chosen for two reasons: (1) it was believed to be a critical source area (large paved area with heavy traffic and where vehicle maintenance is performed), and (2) security for the collection devices was acceptable because a ten-foot chain length fence with razor wire surrounded the lot and security personnel patrolled the area when occupied.

For the testing with the presettled runoff, the filtering column apparatus was moved beside the MCTT and settled runoff was pumped using the peristaltic pump with Masterflex tubing directly from the settling chamber into the flow splitter. For the bench-scale tests, well-mixed runoff was siphoned into two types of collection vessels. One type was the 8 L Nalgene HDPE jug; the other was a 10 L semi-rigid, polyethylene cubitainer (from Fisher Scientific). Approximately 750 liters of runoff was removed from the settling chamber, put into these containers and transported to the lab where it was split into five homogeneous sections, one section for each of the bench-scale runs. When the filter column apparatus was not in use and out in the field, the carousel was covered with a plastic tarpaulin to keep out bugs, bird feces, and anything else that potentially could end up in one or more columns and contaminate the influent to only one column.

Filter media columns were reconstructed after every series of tests, such as between the initial sediment solids loading experiment and the testing on unpresettled runoff, between the unpresettled runoff testing and the bench-scale testing, and between the bench-scale tests and the field testing with presettled runoff. New columns were also constructed for each of the bench-scale tests.

Laboratory Procedures

The laboratory techniques used in this series of experiments were based upon either Standard Methods for Water and Wastewater (APHA 1992) or on EPA-Approved Methods, and they are described in the Quality Assurance Project Plan approved by U.S. EPA for this project (Parmer and Pitt 1995). Some modifications of these methods were required in order to have more effective analyses of the stormwater pollutants. Quality assurance/quality control samples were collected and analyzed in accordance with the laboratory's approved QAPP document. Table 17 lists the chemical analyses that were conducted for each test series.

Table 17. Laboratory analyses

	Toxicity	Physical Character[1]	Hardness	Solid & PSD	COD	Anion & Cation	SVOCs & Pesticides	Heavy Metals
Clogging				X				
Unpretreated runoff[2]	X	X	X	X	X	X	X	X
Neutral pH, salt	X	X	X	X	X			X
Low pH, no salt	X	X	X	X	X			X
High pH, no salt	X	X	X	X	X			X
Low pH, salt	X	X	X	X	X			X
High pH, salt	X	X	X	X	X			X
PreSettled[3]	X	X	X	X	X	X	X	X

1. Turbidity, Conductivity, Color, pH.
2. Runoff: composite from NJ, WI, AL (not allowed to settle before filtration).
3. Runoff: settling chamber of MCTT (allowed to presettle for minimum of three days).

PSD: Particle Size Distribution (4 to 128 µm for bench-scale tests; 1 to 128 µm for long-term performance testing)
SVOC: Semi Volatile Organic Compounds

Initial Test Procedure for the Sand Column

This phase of testing was designed to measure the water retention and characterize the pollutant removal capability of a filter. These results were the determining factor for expanding this project to include evaluation of other media. A sand column was constructed as described above, and water retention testing was done on the new column. Water retention was measured by pouring a specific volume of water through the column (300 mL) and allowing the column to drain overnight. The difference between the influent and effluent volumes of water is the water retention in the column. Next, stormwater runoff from one of the three Stafford Township, NJ, sites was slowly passed through the filter in 100 mL increments. A 40-mL grab sample was collected of the effluent from each of these increments and analyzed for toxicity, turbidity, and conductivity.

When the results of these tests did not agree with Austin results for their sand filters, the possibility of a lack of permanent retention of pollutants in the filter was investigated by performing mass balance analyses on the column. A calibration curve was created for a sodium chloride solution, where concentration was plotted against conductivity. A solution containing a concentration of 4 g/L NaCl (from Fisher Scientific) was made (800 mg NaCl in 200 mL 18 MΩ water) and filtered through a previously wetted column and the conductivity of the effluent was measured. Then 200 mL increments of 18 MΩ water were filtered through the column. The conductivity of the incremental effluents was then measured with the incremental flushing of the filter continuing until the conductivity of the solution was below the detection limit of the conductivity meter (10 µS/cm).

Procedure for Determining the Effects of Sediment Accumulation on Filter Flow Rate

The purpose of these tests was to determine the quantity of solids that could be loaded on the filtration media before flow became 'negligible.' The first phase involved the filter fabrics, along with a sand, an activated carbon, a peat moss, and a sand-peat-mix column, and used the cumulative volume occupied by particles and their size distribution for both the influent and effluent to measure the fabrics' ability to remove solids. This test used runoff composited from several storms at three locations in Stafford Township, NJ.

The second phase was designed to determine cumulative suspended solids loading on the media. A solution of tap water and a local, red clayey soil was used as the filter media influent. This clay-water solution was pumped using the peristaltic pump with Masterflex tubing until the flow 'stopped.' The total solids loading needed to cause clogging was determined from the known concentration and cumulative flow into each column. Next, the depth of red clay penetration into the column was measured visually.

Results from the other experiments, including the bench-scale and both the unpretreated and presettled runoff tests, also were used to determine suspended solids' accumulation on the surface and penetration into the media. Both the bench-scale tests and the tests that used unpretreated runoff had significantly higher influent suspended solids concentrations than the presettled runoff, and physical clogging occurred before chemical breakthrough. For all tests, suspended solids concentrations were measured both for the influent and effluent with the solids accumulation on the media being equal to the difference between the influent and effluent suspended solids concentrations multiplied by the volume of water that passed through the media. When the media's filtration loading rate slowed to less than 5 meters per day (m^3 runoff water/m^2 filter surface area), maintenance was done on the surface of the filter. This maintenance generally included breaking up any mats on the top of and in the top 2 centimeters of the media. In general, disturbance of the top of the media temporarily improved filtration loading rates to more than 5 m/day (but still less than 10 m/day), but disturbance was required after each aliquot of water had been added. When breaking up mats was no longer effective, the maintenance activity of removing the top 1 to 2 centimeters of filter media began. Removal of the top of the media column significantly improved flows (to approximately 10 m/day) temporarily. Visible cakes of solids (approximately 5 mm thick) were also removed from the top of the compost-sand column for the 'low pH, high ionic strength' run and from the top of both the peat-sand and compost-sand columns of the 'high pH, high ionic strength' run when the columns were rebuilt prior to the next run. In spite of the above described maintenance, the peat-sand column clogged during the 'neutral pH, high ionic strength' and the 'high pH, high ionic strength' runs, and the compost-sand clogged during the 'low pH, high ionic strength' and 'high pH, high ionic strength' runs. These columns had to be pulled out of service prior to the completion of the run, with the exception of the peat-sand column in the 'high pH, high ionic strength' run which clogged at the scheduled end of the test.

The 'unpretreated runoff' tests used water that was a composite of runoff from six locations: UAB Remote Transportation Parking Lot, UAB Lot 15 Student Parking Lot in front of the Engineering Building, Ruby Avenue Public Works Garage, and three sites in Stafford Township, NJ. During filtration, the influent water to the columns was stirred regularly to ensure that very few solids could settle out on the bottom. Significant reductions in flow rate were observed after 5.5 m^3 of runoff per m^2 of filter area had been filtered.

The 'presettled runoff' tests used water that had been collected in the settling chamber of the MCTT at least three days prior to the test date. The settling chamber of the MCTT is approximately 1.2 m deep and contains Lamella plates to a height of 0.6 m from the bottom of the chamber. The purpose of the lamella plates is to assist in settling so that after three days, very few particles larger than colloidal size remain in the runoff near the top of the chamber. Because the suspended solids in the presettled water were colloidal, retention of solids was not observed for any of the media even after the fifth storm event although the significant decreases in flow rates indicated physical retention of solids.

Procedure for Bench-Scale Testing (Effects of pH and Ionic Strength on Pollutant Removal)

The bench-scale tests were designed to determine the effects of pH and ionic strength on the ability of the filter media to capture and retain pollutants because other researchers have shown that, for some of the media of interest, pH and ionic strength can significantly influence the ability of an adsorbent both to sorb and to permanently retain pollutants. A series of five experiments, using a full 2^2 factorial (with a midpoint) experimental design, was used to quantify the effect of pH and ionic strength on the removal efficiency and permanent retention ability of the various media of interest (activated carbon, peat, zeolite, compost, ENRETECH, sand). An empty glass column was used as the "blank" or "control." The filter fabrics were not tested as part of this phase since it was assumed that their removal efficiencies for dissolved pollutants would be poor under ideal conditions. The filter fabrics were tested in the field only in order to confirm this assumption. Approximately 600 liters of runoff was collected from the settling chamber of the MCTT after the water had been stirred up to resuspend any solids and transported back to the laboratory where it was split into five equal portions. The portions that were waiting to be used were stored either in 8-L Nalgene jugs or 10-L polyethylene cubitainers.

Immediately prior to each bench-scale run, one portion of the stored runoff was poured into the two-hundred liter Nalgene drum, and the pH and ionic strength were adjusted as necessary. Either concentrated sulfuric acid or sodium hydroxide pellets were used to adjust the pH of the runoff in the desired direction. Dried seawater salt was used to adjust the ionic strength (Aquarium Seawater Salt, from An Urban Jungle, Hoover, AL). The portions were adjusted according to the following scheme:

- low pH, low ionic strength
- low pH, high ionic strength
- high pH, low ionic strength
- high pH, high ionic strength
- neutral pH, high ionic strength

Prior to adjustment, the runoff had a natural pH of about 7 and a specific conductivity of several hundred µS/cm. The pH values were adjusted with sulfuric acid to about 5 (low pH), with sodium hydroxide to about pH 9 (high pH), and no pH adjustment was done for the neutral pH sample. The low ionic strength was unadjusted runoff (200-400 µS/cm), while the medium and high ionic strength solutions were prepared using the evaporated seawater salt. The high ionic strength portions had a conductivity of approximately 10,000 µS/cm. The 'midpoint' portion had a pH of approximately 7 and a conductivity of about 8,000 µS/cm. The filter fabrics were not tested in this phase.

After any adjustments were made to pH and ionic strength, an initial grab sample was made of the well-mixed influent. Six grab samples of influent and effluent from all columns were also captured periodically during each filter run. The first grab was collected after 1/6 of the portion had been filtered, the second after 1/3 (2/6) of the portion had been filtered, etc. At the end of each bench-scale run and after the filters had been allowed to drain (dry) for at least 24 hours, one liter of distilled water was passed through each column to see if future washings would desorb (dislodge) any pollutants. In addition to the analyses listed in Table 17, color adsorption over a continuous range from the ultraviolet to the visible light wavelengths was measured. Additionally, flow rate and cumulative water volume passing through the filter were noted.

Procedure for Long-Term Filtration Performance Testing

Long-term performance information is crucial in designing filters for any application because it determines the required maintenance schedule. One criterion for a good stormwater filter will be the lack of regular maintenance. The long-term performance of these filters was measured in two separate sets of experiments. The first set used composite runoff that had not been presettled. At that time, the media being investigated included sand, activated carbon, peat moss, zeolite, Enretech, compost, and three filter fabrics (ADS 4420, Gunderboom, and EMCON). An empty glass column was included as the "blank" or "control." The activated carbon, peat moss, and zeolite columns contained the 50/50 mixture of adsorbent and sand. The compost and the Enretech were not combined with sand since their manufacturers indicated that they should be used as supplied. Five storm events of composited runoff were treated by the media. During each storm event, two grab samples of effluent were collected (after approximately 25% and 50% of the potential influent had been filtered). In addition to the grab samples, a composite effluent was collected from each column. The grab samples were analyzed for toxicity, turbidity, conductivity, pH, color, chemical oxygen demand, hardness, and particle size distribution (4 to 128 µm range). The composite samples were analyzed for the parameters shown in Table 17.

The in-situ tests were designed to evaluate the long-term removal efficiency for the filter media under conditions similar to that which would be encountered by the filtration media in the MCTT, *i.e.*, the filtration influent was runoff that was allowed to presettle for at least three days. All columns were rebuilt prior to the beginning of this series of tests. Because of its poor performance, one of the filter fabrics, the ADS 4420, was deleted from the design prior to the start of this run, and an additional filter media, the Forest Products Laboratory agrofiber, was added to the list of media to be evaluated. Also, because of the hydraulic problems of the Enretech (compression of media reduced flow significantly) and the compost (flow through media significantly smaller than other media and smaller than desired for the planned application), these media (and the agrofiber, which was expected to act like the Enretech) were mixed with sand in a 50/50 (v/v) mixture, prior to column construction.

Sheetflow samples from the UAB Remote Parking area were collected in the settling chamber of the MCTT and allowed to settle for at least three days before filtration occurred. The columns were not cleaned out and rebuilt between the storm events in order to examine pollutant removal and retention under typical, long-term usage. Presettled runoff also was used because this series of tests was designed to evaluate chemical breakthrough, and the bench-scale tests had shown that physical clogging occurred well before chemical breakthrough when the runoff was not presettled, *i.e.*, chemical adsorption capacity was not completely exhausted before the filter columns clogged. Composite effluents from each filter for each storm event were collected in 8 liter Nalgene HDPE jugs. The composites were then taken back to the laboratory and split into filtered and unfiltered fractions. In addition to the analyses given in Table 17, color adsorption over a continuous range from ultraviolet to visible wavelengths was measured.

Chapter 4
Results and Discussion

Several sets of tests were performed on the filter media and the results of these tests are included in this chapter. The experiments performed include the following:

- Water retention in column
- Mass balance experiments for pollutant flushing
- Sediment clogging
- Bench-scale tests to measure the effect of pH and ionic strength on effluent
- Long-term treatment performance (for both unsettled and presettled runoff)

Initial Test Procedure for the Sand Column

The first test performed on the sand column was a water retention test to determine the volume of water that was retained in the pores of the filter matrix after gravity drainage. This was important in order to evaluate potential carry-over from one filter test to another and, in field use, potential carry-over from one storm event to another. It was determined that approximately 50 mL of water was retained in the column for every 820 cm^3 of sand (the volume of sand in a column with inner diameter of 2.4 cm and height of 45.7 cm).

Further tests using saline solutions were conducted to verify the flushing of the retained water held in the column between tests. The results of the mass balance experiment with the 4 g/L NaCl solution are given in Table 18. These tests showed that the salt water displaced any 'clean' water that was already held in the sand column pore matrix after a single flush. Recovery of the influent salt was 92%. The 8% loss of salt is likely due to one of two possibilities. First, some of the salt reacted with a potential coating on the sand and is 'permanently retained' on the sand. It is unlikely, however, that a significant amount of salt was sorbed onto the sand since this was a new column that contained sand that had not been pretreated to add an adsorptive coating and that had not been allowed to age. The second and more probable explanation is that the detection limit of the conductivity meter was such that accurate measurements of the salt concentration of the standard solution could not be made when the meter read less than 10 - 30 µS/cm. Readings in this range were assumed to contain less than 1 mg of salt.

Table 18. Mass balance data*

	Influent Conductivity (µS/cm)	Effluent Conductivity (µS/cm)	Mass salt in (mg)	Mass salt out (mg)
Salt water influent	6500	2900	800	413
18 MΩ water flush	0	2100	0	324
18 MΩ water flush	0	30	0	<1
18 MΩ water flush	0	30	0	<1
18 MΩ water flush	0	19	0	<1

* The salt water influent volume was 200 mL and the flush water volume was 250 mL.

This initial trapping and subsequent displacement (flushing) was further documented with the filtration of stormwater runoff from Stafford Township, NJ. During filtration of the runoff, the column removed those materials that were causing the water to be toxic to the Microtox™ test luminescent bacteria (measured as percent reduction in luminosity, which is linked to the test organism's respiration). Subsequent filtration of five aliquots of 18 MΩ water, which is not toxic to the luminescent bacteria, had effluent toxicities less than the stormwater influent but that were still toxic (in the low to moderately toxic range). This indicated that the clean water was displacing the trapped toxicants from the pores and resuspending them in the effluent. The results of these tests are given in Table 19, where I25% denotes a specific reduction in bacterial luminosity during the Microtox™ test after 25 minutes of organism exposure to the sample. Three of the later runs of 18 MΩ water through the column had a greater toxicity than the previous run, indicating potential desorption of toxicant from the sand itself.

Table 19. Stormwater runoff filtration in sand columns, measured as toxicity by Microtox™

	Influent (I25 % reduction)	Effluent (I25 % reduction)
NJ runoff	99	22
18 MΩ water	0	32
18 MΩ water	0	27
18 MΩ water	0	37
18 MΩ water	0	5
18 MΩ water	0	28

Based on the Austin stormwater results (Austin, 1988), it had been expected that the sand column would retain any particles that it trapped. However, as the data in Table 19 demonstrates, sand by itself did not retain stormwater toxicants (which are mostly associated with very fine particles), but mostly exchanged (flushed) older retained solutions and fine particulates for newer solutions passing through the column. This lack of ability to retain stormwater toxicants prompted the investigation of other filtration media during this research project. Combinations of filtration media, especially those with a known adsorbent capability such as activated carbon, peat moss, composted leaves, and ion exchange resins, along with sand, were then selected for future testing.

Water retention and hydraulic capacities of the newly chosen media were then tested. The results of these tests showed that water flowed through the activated carbon and zeolite very quickly, which indicated that providing adequate contact time would be a problem. Testing of the peat and compost showed that these media had very slow flow rates and had the potential to compact, which would further decrease their hydraulic conductivities. In order to address these problems, sand was added to the adsorbent media (activated carbon, zeolite, compost, peat moss, Enretech, and agrofiber) in a 50/50 mixture by volume. This slowed the water in the 'fast' activated carbon and zeolite columns and slowed the compression of the other media. Mixing peat and compost with sand allowed channels for water flow and still provided good contact with the media, while preventing the loss of flow capacity due to compression of the media. The newly constructed columns, containing the 50/50 mixture, had more uniform hydraulic conductivities at the start of the tests. Modification of the filter fabrics (which are not considered media for the following discussions) was not performed before any of the testing.

Effects of Sediment Accumulation on Flow Rates of Different Filters

The first phase of this project involved comparing the particulate removal efficiencies of eight filter fabrics and seven filtration media. This was done by comparing the influent and effluent particle size distributions over the range of 4 to 128 µm for each fabric and media. A Coulter Multisizer IIe was used to measure the particle size distributions, and all comparisons were made using the count data (number of particles in each size range). The influent for each medium was a composite of stormwater runoff received from Stafford Township, NJ. The results of the particle size distribution analysis over the range of 6 to 41 µm (which contained 99% of the particles in the influent) are given in Table 20.

Based upon these test results, the filter fabrics and filtration media were divided into four performance classes:

A: Greater than 75% removal for all size ranges
B: Greater than 75% removal of larger particles only (>20 µm)
C: Moderate removal (10 to 50%) for all particle sizes
D: Very low removal for all particle sizes

Table 20. Particulate removal efficiencies

Particle size (μm):	6- 7	>7-10	>10-15	>15-20	>20-25	>25-30	>30-35	>35-40	Overall Removal (%)
Influent distribution (% by count)	77	18	3.1	1.0	0.4	0.2	0.1	0.04	N/A
Fabric removal efficiencies (%) by size									
Holchst 1125	82	80	70	74	13	50	71	N/A	78
Holchst 1120	9	11	16	27	63	40	N/A	N/A	9
Holchst 1135	0	0	0	28	0	0	0	N/A	0
EMCON	28	44	59	90	100	100	100	N/A	37
Exxon	29	49	48	81	60	100	100	N/A	36
ADS 4000	0	0	0	0	0	N/A	0	0	0
ADS 4420	0	0	13	0	0	0	N/A	N/A	3
Gunderboom	75	74	79	93	91	100	N/A	100	70
Filtration media removal efficiencies (%) by size									
Sand	93	92	88	94	N/A	N/A	N/A	N/A	93
Carbon	93	94	98	80	100	N/A	100	N/A	93
Compost Leaf[1]	0	53	29	0	25	N/A	N/A	N/A	16
Peat	31	69	79	73	93	N/A	N/A	N/A	47
Soil[2]	95	92	94	100	100	N/A	N/A	N/A	94

[1] Compost Leaf in these tests was a local composting leaf mixture (leaves still visible), not the medium sold by CSF Systems, Inc. These results are not directly applicable to the mixture supplied by Stormwater Management, Inc. (formerly CSF Systems, Inc.).

[2] Soil is a local (Birmingham, AL area) soil collected near UAB. The soil column was constructed in a similar manner to the other columns (not taken and used as a soil core).

N/A: Individual influent-effluent pairs were collected for each medium or fabric (approximate influent distribution, based on a single sample, is shown in the top row) and N/A indicates that, for that medium or fabric, no particles in the given size range were found in the influent.

Table 21 classifies the fabrics and media according to the above categories. The table also provides a descriptor of the flow rate through the medium, any comments related to the flow through the medium, and an estimate of the clogging potential of each filter. The clogging potential was defined as the maximum suspended solids load, in kilogram per square meter of filter area, that could be loaded on the medium before excessive head loss occurred.

Once the additional filter media had been selected, new columns were constructed, and the water retention characteristics and flow rate of each medium were determined. The flow rate tests provided a ranking, from highest to lowest, of the media: sand > zeolite-sand >> composted leaves ≥ carbon-sand > compost-sand > peat-sand > Enretech-sand > Agrofiber-sand. The filter fabrics selected for further testing, ADS 4420, Gunderboom, and EMCON, had significantly higher flow rates than any of the media.

Table 21. Performance classification for filter fabrics and media

	Fabric/Media	Flow Rate	Clogging Potential	Comments
Category A High efficiency (6 to 41μm)	Holchst 1125 Gunderboom Sand Carbon Soil	Fast Slow Fast Very Fast Slow	3 kg/m^2 0.5 kg/m^2	5+ cm of head needed for flow
Category B High efficiency (>20μm)	EMCON Exxon Peat	Fast Very Slow Slow	0.2 kg/m^2	10+ cm of head needed for flow
Category C Mod. Efficiency (6 to 41μm)	Holchst 1120 Comp. Leaf[1]	Fast Very Fast	2 kg/m^2	
Category D Poor efficiency (6 to 41μm)	Holchst 1135 ADS 4000 ADS 4420	Fast Fast Fast		

1 Comp. Leaf in this table refers to a local composting leaf mixture (leaves still visible), not the filter media sold by CSF Systems, Inc. These results are not directly applied to the medium sold by Stormwater Management, Inc. (formerly CSF Systems, Inc.).

Once the flow rate testing was complete, additional clogging tests were conducted. The solution used for the clogging tests was a clay mixed in water (approximately 6 g/L). The red clay was selected because it would be visible in the column even in areas where the concentration was low, thus allowing visual depth of penetration measurements to be taken. The results of these tests are given in Table 22. Once the clogging tests were completed, the selection of media was re-evaluated, and it was decided to substitute the CSF compost (a pre-prepared media for which pollutant removal information was available) for the local composting leaf mixture, as well as remove the soil from consideration as a viable filtration medium.

Table 22. Clogging results for initial media

Filtration media	Maximum suspended solids loading at clogging (g/m^2)	Avg. penetration depth at clogging (cm)	Penetration into column (% of media depth)
Sand	4000	3.8	13
Composted leaf*	2100	5.1	17
Peat	200	0.6	2
Soil	630	0.3	1
Peat-sand	1700	2.5	10

* Composted leaf in this table refers to a local composting leaf mixture, not to the filter media sold by CSF Systems, Inc.

The clogging tests were then performed on the newly selected media and media-sand combinations. The results of the new clogging tests are given in Table 23. Visual observation of the red clay penetration into the filter media showed the development of channels that the clayey water flowed through, thus allowing it to penetrate further into the filter medium, yet also allowing it to avoid interacting with the top few centimeters of the media. Penetration is beneficial in that it allows for more of the filter depth to be used for treatment; however, bypassing of the media could become a problem for shallow filters.

Graphs showing the effect of suspended solids' loading on flow rate for each medium which was used in the bench-scale testing as well as the in-situ tests (carbon-sand, compost-sand, Enretech-sand, peat-sand, sand, and zeolite-sand) are in Appendix A. This effect of suspended solids' loading on the flow rate through sand is demonstrated in Figure 4-1. As seen in the figure, even a very small suspended solids loading caused a dramatic and rapid reduction in the water flow rate through the column. However, this rapid reduction in flow capacity does not hold true once the flow is decreased to about 20 m/day. At that point, the curve becomes nearly flat, and filtration will continue for three-to-four times as long as the time required to reduce the flow rate to about 20 m/day.

Table 23. Clogging test results for newly selected media

Filtration media	Range of suspended solids loading at clogging (g/m^2)	Avg. penetration depth at clogging (cm)	Penetration depth as % of filter depth
Sand	1200-4000(a)	3.8	9
Peat-sand	200-1700(a)	2.5	5
Carbon-sand	500->2000	3.8	9
Zeolite-sand	1200->2000	5.0	11
Compost-sand	350-800	2.5	5
Enretech-sand	400-1500	2.5	5
Forest-sand	75-300	2.5	5
EMCON	3800	0.1-0.2(b)	N/A
Gunderboom	3800	0.1-0.2(b)	N/A

(a) Results from characterization of each initial media; tests not rerun.

(b) This is the height of the solids cake that formed on the top of the filter fabric, not a penetration depth into the fabric.

Table 24 gives filtration capacity as a function of suspended solids' loading. This information is important because the maintenance requirements of the filters are based on the predicted life of the filter, which is dependent upon both the influent suspended solids' concentration and the amount of solids that have already accumulated on top of the filter. The wide range in filter loading capacity to reach a pre-selected 'undesirable' flow rate results from the variety of suspended solids' concentrations and particle size distributions in the influents of the runs that were used to create Table 23.

Table 24. Treatment capacity as related to suspended solids loading*

Media	Loading to 20 m/day (g/m^2)	Loading to 10 m/day (g/m^2)	Loading to <1 m/day (g/m^2)
Sand	150-450	400->2000	1200-4000
Carbon-sand	150-900	200-1100	500->2000
Peat-sand	100-300	150-1000	200-1700
Zeolite-sand	200-700	800-1500	1200->2000
Compost-sand	100-700	200-750	350-800
Enretech-sand	75-300	125-350	400-1500

* Forest-sand (Agrofiber-sand) was not tested for clogging; however, its behavior is expected to be similar to the behavior of Enretech-sand, since both media are fibrous. This assumption of similarity in flow rates was found to be true in future testing (long-term performance testing).

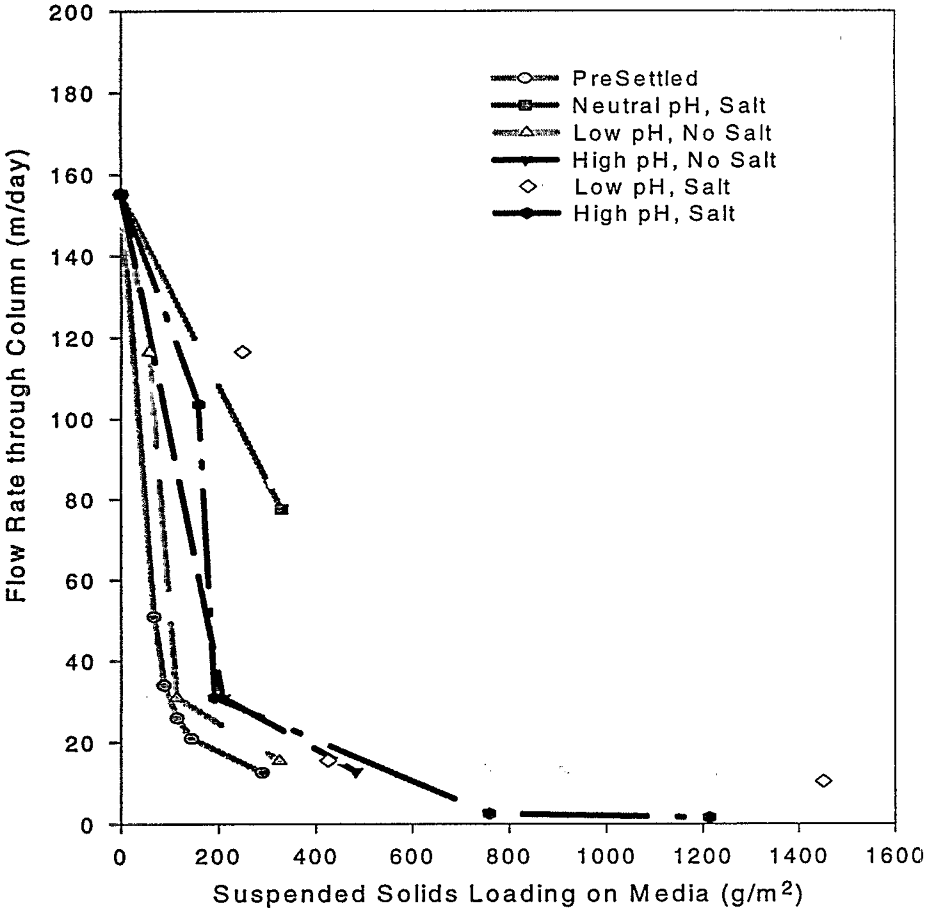

Figure 4-1. Flow rate vs. suspended solids loading on sand

Effects of pH and Ionic Strength on Pollutant Removal

The literature search indicated potential problems with filtration and sorption when the influent is not near neutral pH or has a high ionic strength. In order to investigate these possible effects, a series of five controlled laboratory experiments comprising a full-factorial experiment (including an intermediate position) was conducted. The full factorial experiment consisted of testing combinations of low and high influent pH and ionic strengths for newly constructed columns (low pH and low ionic strength; low pH and high ionic strength; high pH and low ionic strength; high pH and high ionic strength). By testing these factors in the combinations, it could be determined if a factor or the combination of the factors affected the removal capability, while performing a minimum number of tests. Testing of the midpoint was performed (pH = 7; conductivity = 7500 μS/cm) in order to mimic snowmelt runoff. The influent pH and conductivities for the bench-scale tests are in Table 25.

Table 25. Influent characteristics for bench scale tests

	pH	Conductivity (μS/cm^2)
Neutral pH, moderate salt	6.88 – 7.05	7800 – 8500
Low pH, no salt	4.80 – 5.18	290 – 318
High pH, no salt	9.46 - 10.00	200 – 210
Low pH, high salt	4.50 - 5.41	8900 – 9050
High pH, high salt	9.50 - 10.96	7500 – 7900

The test water was collected from the settling chamber of the MCTT. The pH of the influent was adjusted using either reagent grade sulfuric acid (from Fisher Scientific) or reagent grade sodium hydroxide (from Fisher Scientific). The salt content of the influent was adjusted using a sea water salt sold locally for use in saltwater aquariums. The filter media used in these tests included carbon-sand, peat-sand, zeolite-sand, compost-sand, Enretech-sand, and sand, as well as an empty glass column used as a 'blank' to collect a sample of the influent reaching each filter.

During each run, six 500-mL grab samples were collected of the effluent from each column. These grab samples were not split into filtered and unfiltered fractions. The samples were collected after about 3.5, 6.5, 9.5, 12.5, 16 and 21 L of sample had passed through each column. This corresponds to hydraulic loadings on the columns of 1.9, 3.6, 5.2, 6.9, 8.8, 11.6 m (m^3 water/m^2 filter area). At least one day after the run was complete, each column was rinsed with one liter of distilled water. This effluent was collected and analyzed to determine what, if any, toxicants were flushed out of the media in the presence of a relatively aggressive water. Each sample was analyzed for toxicity, turbidity, color, pH, chemical oxygen demand (COD), UV-visible light adsorption, hardness, suspended solids, particle size distribution, and heavy metals (cadmium, copper, lead, and zinc).

Clogging Observations

Near the end of each run, all the filters had significantly reduced flow rates. Several filters clogged completely before the tests were completed. The peat-sand column clogged during the 'neutral pH, moderate ionic strength' run after a hydraulic loading of approximately 7 m. The compost-sand column clogged during both the 'high ionic strength runs.' This clogging occurred after a hydraulic loading of approximately 7 m in the 'high pH' run and after 12 m during the 'low pH' run. The effects of the suspended solids loading on the flow rate in each medium during each run are incorporated into the graphs in Appendix A.

Analysis Results

Tables containing the laboratory analysis results for the various parameters analyzed in the bench-scale tests are in Appendix B, as are the graphical representations of the results. Statistical analysis of this data was performed by two independent methods. A one-tailed Wilcoxon sign-rank analysis (procedure described in Lehmann, 1975) was used to test the hypothesis that filtration would not significantly change the influent concentration for the parameter of interest. P values less than 0.10 are considered significant and lead to the conclusion that filtration significantly affected the concentration of a given parameter. The Wilcoxon sign-rank analysis was selected because it is a nonparametric, paired-sample test, *i.e.*, no underlying distribution of the data is assumed. It has not been demonstrated that stormwater runoff or filter effluent samples follow a specific statistical distribution such as the normal or log-normal distributions and therefore, a nonparametric test was required. If a distribution had been assumed for the data, then other tests of paired samples could have been used, and more statistically significant results likely would have been found. The weakness of this test as it was run is that the P values do not indicate whether the significant changes that occurred during filtration were a reduction or an increase in a parameter's concentration. The tables in each of the following subsections contain the P-values from the Wilcoxon sign-rank analysis for each parameter. P values for significant reductions are given in italics to distinguish them from significant increases in concentrations or inconsistent removals.

The second statistical test performed was a factorial analysis for the four bench-scale tests where both pH and ionic strength were modified. This allowed the effects of influent pH, influent ionic strength and the combination of the two factors to be evaluated in only four test runs. The midpoint (pH 7, ionic strength 7500 µS/cm) was also tested to mimic snowmelt runoff conditions. The detailed procedure for performing the factorial analysis is given by Berthouex and Brown (1994) and for interpreting the results is given in Box, Hunter and Hunter (1978). In general, pH, ionic strength, or the interaction of the two was considered significant when the calculated effect for each influence was greater than three times the group standard error. Factorial analysis was performed on two sets of results for each parameter: the effluent concentrations, and the removal efficiency, measured as percent decrease, in a constituent due to filtration. The tables of contrast for each of the analyses are also located in Appendix B.

Toxicity

The Wilcoxon sign-rank analysis P values for toxicity are given in Table 26. These results showed that none of the media were capable of reducing the toxicity of the influent under all conditions of pH and ionic strength although the compost was effective under all conditions except high pH and high ionic strength and the only medium capable of significant removal of toxicity at the midpoint conditions (influent: pH 7, ionic strength 7500 µS/cm).

One possible explanation for why no single medium was capable of reducing toxicity under all conditions likely is directly related to the test organisms used in the Microtox™. The luminescent bacteria, *Photobacterium phosphoreum*, are a marine bacteria and therefore require a salt water environment to live. Previous research by Ayyoubi (1993) with the Microtox™ proved that there was a wide range of salt concentrations at which these test bacteria performed at their optimum. However, there is an upper limit after which the bacteria cannot survive, and the effluent samples from the high ionic strength tests likely exceeded that upper limit. Like most organisms, these bacteria also have a narrow pH range at which they live. For most of the runs where there was no significant reduction in toxicity during filtration, it is likely that since the influent pH was outside of this range, the effluent pH was also outside the tolerable range for *P. phosphoreum* because most of the media did not significantly move the pH toward neutral.

Table 26. Wilcoxon P values for toxicity*

Filtration Media	Neutral pH, Mod. Salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	0.25	*0.03*	*0.02*	*0.03*	0.13
Peat-sand	0.56	*0.03*	*0.02*	0.06	*0.02*
Zeolite-sand	0.13	0.13	0.28	*0.02*	0.50
Compost-sand	*0.06*	*0.03*	*0.02*	*0.03*	0.13
Enretech-sand	0.69	0.41	0.42	0.41	0.50
Sand	0.31	*0.08*	0.69	*0.05*	0.16

* Probability that influent and effluent have the same concentration.

The factorial analysis showed that the effluent toxicities of the carbon-sand and zeolite-sand columns were controlled by the interaction of pH and ionic strength, with the high pH, high ionic strength condition having the most toxic effluent. The removal efficiency, however, was controlled by ionic strength for the carbon-sand and by pH for the zeolite-sand. High influent salt concentrations caused an increase in the toxicity of the carbon-sand effluent while a high influent pH caused an increase in toxicity of the zeolite-sand effluent. The high influent ionic strength made the peat-sand effluent more toxic while the removal efficiency for toxicity across this medium was controlled by the interaction of the pH and the salt. High influent pH caused an increase in the toxicity of the Enretech-sand effluent. The effluent toxicity for the sand medium was controlled both by the influent pH and ionic strength independently. However, the removal efficiency was controlled by the interaction of the ionic strength and the pH.

Turbidity

Table 27 gives the results of the Wilcoxon sign-rank analysis for turbidity. These results were as expected for most of the media. The carbon-sand and the zeolite-sand columns were excellent removers of turbidity both due to sorption of the contaminants and due to physical straining of unsorbed particulates. The peat-sand contributed particles to the effluent because many of the particles that were washed from the peat during filtration were too small to be strained out during filtration through the bottom sand layer. In general, the sand column strained out the particles during filtration. The other media had mixed results, indicating that they would not be good for use in areas that are likely to receive runoff with a variation of pH conditions and salt concentrations.

Table 27. Wilcoxon P values for turbidity

Filtration media	Neutral pH, mod. Salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Peat-sand	0.44	0.06	0.02	0.11	0.34
Zeolite-sand	*0.02*	0.16	*0.06*	*0.02*	*0.02*
Compost-sand	*0.02*	0.11	0.06	0.16	0.12
Enretech-sand	*0.02*	0.16	0.16	*0.03*	*0.02*
Sand	*0.02*	0.54	*0.08*	*0.02*	*0.02*

The influent ionic strength and pH generally did not influence the effluent turbidity, except for the zeolite-sand. The zeolite-sand effluent turbidity was controlled by the influent ionic strength, with the lower effluent turbidities occurring when the influent ionic strength is high. The efficiency of filtration is controlled by the interaction of the influent pH and ionic strength (high influent pH and salt concentrations caused the smallest average percent removal across the media). For the carbon-sand and peat-sand media, the influent ionic strength controlled the removal efficiency (high influent salt concentration conditions caused greater turbidity removal in the carbon-sand and smaller addition of turbidity in the peat-sand). For the Enretech-sand and the sand media, the influent pH and ionic strength independently controlled the removal efficiencies (both high influent pH and high influent salt concentrations increased the removal efficiency of these media).

Conductivity

The Wilcoxon sign-rank analysis P values are given in Table 28. Since conductivity is caused by charged ions which are dissolved in solution, conductivity will only be removed by media that are capable of removing dissolved ions, especially the monovalent sodium and chloride ions. Most of the media are ion-exchange resins that are not good at removing sodium and chloride. In fact, they add sodium to the solution when they remove other compounds because the compounds sorb at the locations on the media where the sodium is held. Although several of the media show significant reductions in conductivity, the size of the reductions is very small (less than 20 percent). Because ionic strength is one of the parameters that were being controlled, the results of a factorial analysis would be meaningless and, therefore, are not presented.

Table 28. Wilcoxon P values for conductivity

Filtration media	Neutral pH, Mod. salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	0.31	0.22	0.06	0.02	0.38
Peat-sand	0.02	0.50	0.02	0.03	0.02
Zeolite-sand	0.02	0.50	0.08	0.06	0.02
Compost-sand	0.02	0.03	0.05	0.03	0.50
Enretech-sand	0.02	0.22	0.36	0.16	0.16
Sand	0.06	0.11	0.54	0.02	0.45

Color

Table 29 gives the P values for the Wilcoxon sign-rank analysis for color. Based on the literature, carbon-sand was expected to remove color because it can sorb the organic acids that cause color in the runoff, and carbon-sand, in fact, was found to remove color under all test conditions. Peat and compost leach these color-producing organic acids during filtration; therefore, they were not expected to remove color from the influent. In fact, these two media significantly increased the effluent color. The other media only removed color during favorable conditions for that medium.

Influent pH controls the final effluent color only for the peat-sand filter with a high influent pH producing high effluent color. The final effluent color of the carbon-sand and zeolite-sand is influenced by the influent salt concentration. High influent ionic strength produces more color in the carbon-sand effluent but less color in the zeolite-sand effluent. The removal efficiency in the peat-sand column was controlled by the interaction of the influent pH and ionic strength (largest average removal occurred in low pH, high salt conditions). The influent ionic strength controls the removal efficiency in the zeolite-sand column (high influent salt concentrations caused greater removal of color). Influent pH controls the removal efficiency (high influent pH caused less color addition to the effluent). The removal efficiency for color in the sand column is controlled by the influent pH and salt concentration independently.

Table 29. Wilcoxon P values for color

Filtration media	Neutral pH, mod. Salt	Low pH, no salt	High pH, No salt	Low pH, salt	High pH, salt
Carbon-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Peat-sand	0.31	0.06	*	0.03	0.02
Zeolite-sand	0.16	*0.09*	*0.03*	*0.02*	*0.02*
Compost-sand	0.02	0.02	*	0.02	0.02
Enretech-sand	0.66	0.34	*0.02*	*0.02*	*0.02*
Sand	0.58	0.08	*0.02*	*0.02*	*0.02*

* No difference notable between influent and effluent color for these columns; therefore, no results for Wilcoxon sign-rank analysis.

pH

The Wilcoxon sign-rank P values are given in Table 30. For this parameter, italics refer to cases where the pH was brought closer to 7. Only two of the media showed significant changes in the pH of the effluent. The compost-sand always tried to move the pH toward neutral, even with both low and high pH influents. The peat-sand always tried to lower the pH between 1 to 1.5 units, even when the influent pH was already in the pH 4 to 5 range. When the influent pH was greater than 7, the peat-sand lowered the pH in the effluent (compared to the influent) by 1.5 to 3 units. The carbon-sand, the zeolite-sand, and the sand all attempted to increase the pH when the influent pH is low. However, these media did not consistently reduce the pH when the influent pH is high. Since pH is one of the parameters being controlled, the results of a factorial analysis would be meaningless and, therefore, are not presented.

Table 30. Wilcoxon P values for pH

Filtration media	Neutral pH, Mod. Salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	0.02	0.02	0.02	0.02	0.02
Peat-sand	0.31	0.02	*0.02*	0.02	*0.02*
Zeolite-sand	0.02	0.02	0.50	0.02	0.02
Compost-sand	0.66	*0.02*	*0.02*	*0.02*	0.13
Enretech-sand	0.08	0.34	0.02	0.02	0.02
Sand	0.02	0.09	0.02	0.02	0.03

Hardness

Table 31 gives the Wilcoxon sign-rank P values for hardness. Hardness reductions were expected for those media that could remove divalent cations either during sorption or ion-exchange (such as zeolite). The carbon-sand is the only medium which consistently reduced the hardness in the influent. The other media either were inconsistent at reducing the hardness, or they exchange divalent cations into solution. Because the zeolite chosen for these experiments was designed as an ammonia remover, it was not expected to be as effective at removing hardness as other zeolites that are designed to remove calcium from water.

The interaction of influent pH and ionic strength did not affect the effluent hardness for any media. However, the hardness in the effluent from all of the media was influenced either by the influent pH, salt concentration, or both pH and ionic strength acting independently. The influent pH controls the effluent hardness for both the Enretech-sand and the peat-sand (higher hardness values occurred when the influent pH was low). The influent ionic strength controls the effluent hardness for the zeolite-sand column (higher hardness occurred when the influent salt concentration was high). The influent pH and ionic strength, acting independently, influence the effluent hardness for the other media, the carbon-sand, compost-sand, and sand (highest effluent hardness concentration occurred for each medium when the influent pH was low and the influent salt concentration was high). The influent pH controls the removal efficiency of both the carbon-sand and the peat-sand media (higher removal efficiencies occurred when the influent pH was greater than 7). The influent ionic strength controls the removal efficiency for the zeolite-sand and compost-sand media (smallest addition to the hardness occurred when the influent salt concentration was low).

Table 31. Wilcoxon P values for hardness

Filtration media	Neutral pH, Mod. salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.03*	*0.03*	*0.02*	*0.02*	*0.02*
Peat-sand	0.02	0.03	*0.02*	0.16	*0.02*
Zeolite-sand	0.02	0.22	0.22	0.02	0.02
Compost-sand	0.02	0.02	0.03	0.02	0.02
Enretech-sand	0.08	0.50	0.64	0.59	*0.08*
Sand	0.46	*0.03*	*0.05*	*0.03*	0.22

Chemical Oxygen Demand (COD)

The calculated P values for the Wilcoxon sign-rank analysis are given in Table 32. Chemical oxygen demand was consistently removed by all of the media except compost-sand under all influent conditions. The Enretech-sand and sand media also reduced COD influent concentrations for all conditions except for high pH and no salt addition. As is demonstrated in Figure 4-2, the influent (control) chemical oxygen demand appears to be related to the influent (control) suspended solids concentration. This indicates that the media which can remove particulates from the solution and retain them in their pores are the ones most likely to be able to remove chemical oxygen demand during filtration. This mimicry of the suspended solids concentration is also seen in the COD of the filter effluents. Therefore, both the influent and effluent COD are directly related to the influent and effluent suspended solids concentration.

Table 32. Wilcoxon P values for chemical oxygen demand

Filtration media	Neutral pH, Mod. salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Peat-sand	*0.06*	*0.02*	*0.08*	*0.02*	0.62
Zeolite-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.03*
Compost-sand	0.13	*0.06*	*0.06*	0.22	0.22
Enretech-sand	*0.03*	*0.02*	0.22	*0.02*	*0.02*
Sand	*0.02*	*0.02*	*0.08*	*0.02*	*0.02*

The effluent COD concentration was controlled by the interaction of the influent pH and ionic strength for five of the six media, including carbon-sand, peat-sand, zeolite-sand, compost-sand and sand. The highest effluent COD concentrations occurred when the influent pH and salt concentrations were high for the carbon-sand, peat-sand, zeolite- sand and compost-sand. A low influent pH and a high influent salt concentration caused sand's highest effluent COD concentration. The Enretech-sand filter was the only one whose effluent COD concentration was not controlled by the interaction of the influent pH and ionic strength. The effluent COD for Enretech-sand is controlled only by the influent ionic strength (high influent salt concentration caused high effluent COD). The removal efficiency of the peat-sand filter was controlled by the influent pH (greatest percent removal occurred when the influent pH was less than neutral). The interactions of the influent pH and ionic strength controlled the removal efficiencies of both the carbon-sand and sand media. The greatest percent removal of COD occurred for carbon-sand when the influent pH was high and influent salt concentration was low, and the greatest percent removal for sand occurred when both the influent pH and salt concentration were high.

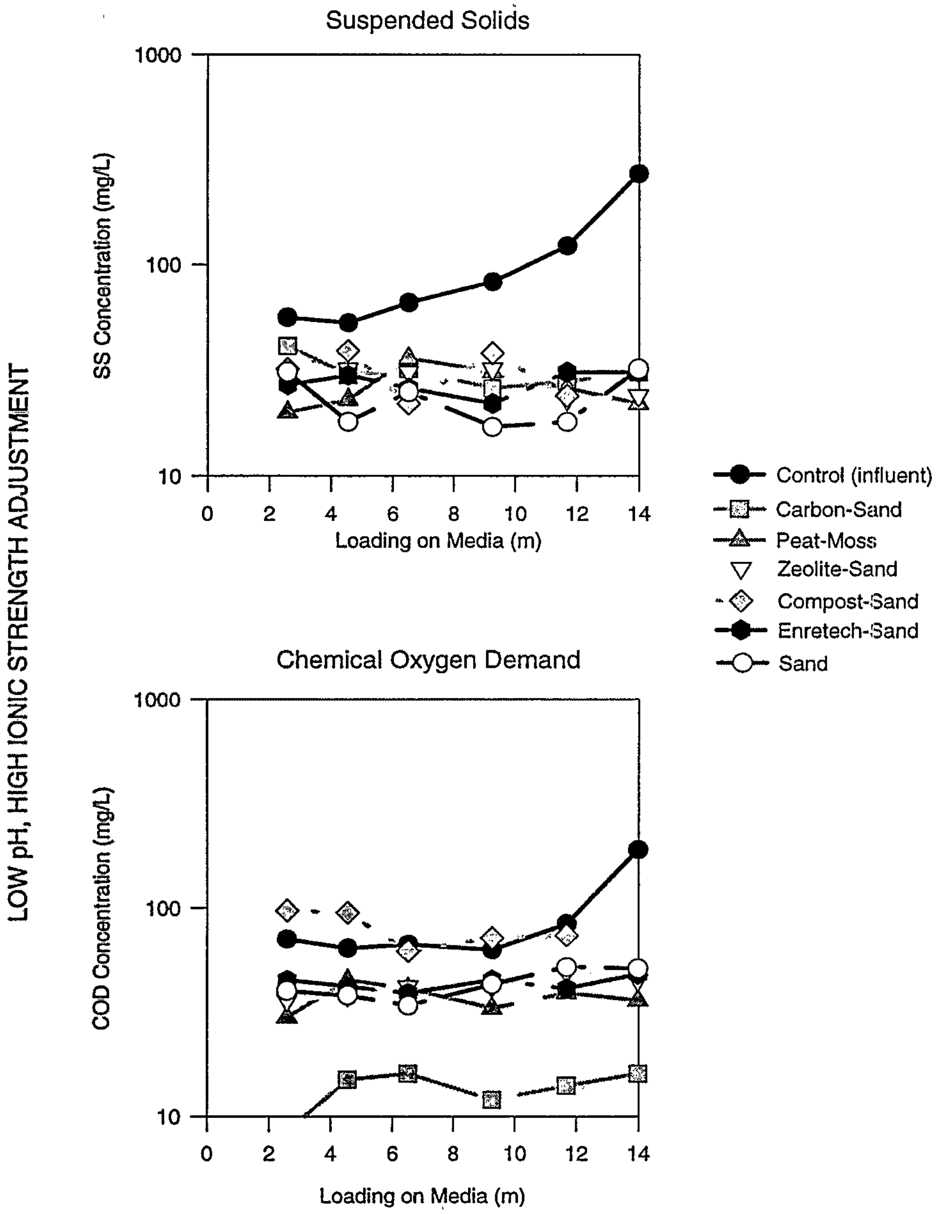

Figure 4-2. Effluent suspended solids and chemical oxygen demand concentrations versus suspended solids loading on media

Particle Size Distribution (4 to 128 μm)

Table 33 gives the calculated P values for the Wilcoxon sign-rank analysis. Except for the peat-sand during high pH, high ionic strength influent conditions, all media were excellent at removing particles across the size range of 4 to 128 μm. The factorial analysis for the cumulative particle size distributions for these media show that neither the pH nor the ionic strength controls either the removal efficiency or the effluent quality. There also were no observed significant effects of the interaction of pH and ionic strength on removal efficiency and effluent quality.

Table 33. Wilcoxon P values for PSD (4 to 128 μm)

Filtration media	Neutral pH, Mod. Salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Peat-sand	*0.06*	*0.02*	*0.08*	*0.02*	0.62
Zeolite-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Compost-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Enretech-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*

Particle Size Distribution (6 to 8 μm)

Table 34 gives the calculated P values for the Wilcoxon sign-rank analysis for the particle size distribution in the 6 to 8 μm range. All media were capable of removing the smaller-sized particles from the influent with the exception of the compost-sand filter at the high influent pH, high influent ionic strength condition.

Table 34. Wilcoxon P values for PSD (6 to 8 μm)

Filtration media	Neutral pH, mod. Salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Peat-sand	*0.06*	*0.02*	*0.02*	*0.03*	*0.02*
Zeolite-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Compost-sand	*0.02*	*0.02*	*0.02*	*0.03*	0.13
Enretech-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*

The influent pH controlled both the effluent quality and removal efficiency for the peat-sand filter (low influent pH resulted in the best effluent quality and removal efficiency). The influent ionic strength also independently influenced the peat-sand's effluent quality (high influent ionic strength resulted in the best effluent quality). The influent ionic strength controlled both the effluent quality and removal efficiency for the Enretech-sand filter (best effluent quality and removal efficiency occurred when the influent salt concentration was high).

Particle Size Distribution (20 to 22 μm)

Table 35 gives the calculated P values for the Wilcoxon sign-rank analysis. Except for the compost-sand during the high influent pH, high influent salt condition, all media were capable of removing the medium-sized particles from the influent. The factorial analyses showed that influent pH, influent ionic strength, or the interaction of pH and ionic strength did not control the effluent quality or removal efficiency for any of the media except peat-sand. The interaction of influent pH and influent high ionic strength controlled the removal efficiency of the peat-sand filter (worst average removal efficiency occurred when the influent pH was high and the influent salt concentration was low).

Table 35. Wilcoxon P values for PSD (20 to 22 μm)

Filtration media	Neutral pH, mod. Salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Peat-sand	*0.06*	*0.02*	*0.02*	*0.03*	*0.02*
Zeolite-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Compost-sand	*0.02*	*0.02*	*0.02*	*0.03*	0.13
Enretech-sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*
Sand	*0.02*	*0.02*	*0.02*	*0.03*	*0.02*

Particle Size Distribution (52 to 54 μm)

The calculated P values from the Wilcoxon sign-rank analysis are given in Table 36. All media, with two exceptions, were capable of removing the larger-sized particles from the influent. The exceptions were the compost-sand filter at the high influent pH, high influent ionic strength condition, and the peat-sand at a neutral pH, moderate ionic strength condition. The factorial analyses indicate that neither pH, ionic strength, nor the interaction of pH and salt controlled either the effluent quality or the removal efficiency of the media.

Table 36. Wilcoxon P values for PSD (52 to 54 μm)

Filtration media	Neutral pH, mod. salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.06*	*0.02*	*0.02*	*0.03*	*0.02*
Peat-sand	0.25	*0.02*	*0.02*	0.22	*0.02*
Zeolite-sand	*0.06*	*0.02*	*0.02*	*0.03*	*0.03*
Compost-sand	*0.08*	*0.02*	*0.02*	*0.03*	0.12
Enretech-sand	*0.06*	*0.02*	*0.02*	*0.09*	*0.02*
Sand	*0.06*	*0.02*	*0.02*	*0.03*	*0.02*

Suspended Solids

Table 37 gives the calculated P values for the Wilcoxon sign-rank analysis for suspended solids. Except for the compost-sand at the high influent pH, high influent ionic strength condition, all media were capable of removing suspended solids from the influent. For all media, the quality of the effluent was controlled by the interaction of the influent pH and ionic strength. The low influent pH and high influent salt concentration had the highest average suspended solids concentration in the effluent. The removal efficiency of none of the media was controlled by the influent pH or ionic strength acting independently. For the carbon-sand and the zeolite-sand media, the interaction of the influent pH and ionic strength controlled the removal efficiency. For these media, the poorest removal efficiency occurred when the influent pH was low and the influent salt concentration was high.

Table 37. Wilcoxon P values for suspended solids

Filtration media	Neutral pH, mod. salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Peat-sand	*0.06*	*0.02*	*0.02*	*0.02*	*0.02*
Zeolite-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Compost-sand	*0.02*	*0.02*	*0.02*	*0.03*	0.12
Enretech-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*

Zinc

The calculated P values for the Wilcoxon sign-rank analysis are given in Table 38 for zinc. Except for the compost-sand during the high influent pH, high influent ionic strength condition, all media were capable of significantly removing zinc from the influent during filtration. Effluent quality was controlled by the interaction of the influent pH and ionic strength for four media: peat-sand, zeolite-sand, Enretech-sand, and sand. For each of these media, the effluent quality was poorest when the influent pH was low and the influent salt concentration was high. For the carbon-sand and peat-sand filters, the effluent quality and removal efficiency were controlled by the influent pH (worst average effluent quality and removal efficiency occurred when the influent pH was low).

Removal efficiency was controlled by the interaction of the influent pH and influent ionic strength for three of the media: zeolite-sand, compost-sand, and sand. The smallest removal efficiency occurred for each medium when the influent pH was low and the influent salt concentration was high. The Enretech-sand filter's effluent quality was controlled by the influent pH and influent ionic strength acting independently. For Enretech-sand, low influent pH, low influent salt concentrations, or both caused poorer average removal efficiencies.

Table 38. Wilcoxon P values for zinc

Filtration media	Neutral pH, mod. Salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Peat-sand	*0.06*	*0.02*	*0.02*	*0.02*	*0.02*
Zeolite-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Compost-sand	*0.02*	*0.02*	*0.02*	*0.02*	0.13
Enretech-sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*

Copper

Table 39 gives the calculated P values for the Wilcoxon sign-rank analyses for copper. Most of the media were able to remove copper from the solution during most tests. However, the carbon-sand, peat-sand, and zeolite-sand were not able to significantly remove copper from the influent when the pH was neutral. However, the solution had a moderate ionic strength (salt was added to the runoff), which may have affected copper removal.

Table 39. Wilcoxon P values for copper

Filtration media	Neutral pH, mod. Salt	Low pH, no salt	High pH, no salt	Low pH, salt	High pH, salt
Carbon-sand	0.41	*0.02*	*0.02*	*0.02*	*0.02*
Peat-sand	0.50	*0.02*	*0.02*	*0.02*	*0.02*
Zeolite-sand	0.28	*0.02*	*0.08*	*0.02*	*0.02*
Compost-sand	*0.02*	*0.02*	*0.02*	*0.03*	0.13
Enretech-sand	*0.02*	*0.02*	0.22	*0.02*	*0.02*
Sand	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*

The factorial analyses showed that the final effluent quality was controlled by the interaction of the influent pH and influent ionic strength for four of the media: peat-sand, zeolite-sand, Enretech-sand, and sand. The poorest effluent quality was found when the influent pH and salt concentration were low for the peat-sand, zeolite-sand, and Enretech-sand media. The sand's effluent quality was worst when the influent pH was low and the influent salt concentration was high. For the compost-sand filter, effluent quality was controlled by the influent pH and influent ionic strength acting independently. The removal efficiency for five of the media, peat-sand, zeolite-sand, compost-sand, Enretech-sand, and sand were controlled by the interaction of the influent pH and ionic strength. For all five media, the poorest removal efficiency occurred when the influent pH was high and the influent salt concentration was low.

Other Observations

The expected significant clogging of the filter media with the suspended solids was found during the tests. The UV-vis absorbance test evaluations showed some, but limited, decrease in sorption capacity during the tests. The clogging was affected by changes in pH and ionic strength. The changes in pH and ionic strength also affected the permanent retention of the pollutants in the columns after the tests. No chemical breakthrough was noted for any of the tests during the test durations; the columns clogged and ceased to allow filtration before their chemical removal capacity was exceeded.

Clogging of the peat-sand filter occurred during the neutral pH, high ionic strength run, but not during the other runs (except at the end of the high pH, high ionic strength run), indicating that filtering influents with high conductivities will reduce the life of the filter, while either a significantly acidic or alkaline influent will tend to prolong the filter run. The clogging of the compost-sand filter during both the high ionic strength tests (low and high pH) indicates that filtering influents with high conductivities will reduce the life of the filter, and, unlike peat, a significantly acidic or alkaline runoff does not appear to prolong the life of the filter.

Long-Term Treatment Performance

Evaluation of long-term treatment performance was performed on two separate occasions by filtering runoff that had not been allowed to presettle through the columns as the first run and presettled runoff through the columns as the second run. The purpose of these tests was to determine chemical breakthrough during filtration of a complex influent. The literature search had indicated that most of these media were effective at removing pollutants under laboratory conditions with analytical grade chemicals used to spike water or an organic solvent. Although these tests were informative about the chemicals that each media could remove and the potential removal mechanisms, relatively few tests had been done using a more 'complex' influent, *i.e.*, where some compounds are present in more than one form and where there is likely significant competition for the removal sites. This is the reason that the location selected to study the runoff was a potential critical source area -- the intention was to use the 'dirtiest' runoff water that could be obtained easily and from a location where the sampling equipment was secure. However, this runoff was not as dirty as expected because only the fueling operations and vehicle cleaning operations were outdoors. Fleet vehicle maintenance was performed in a garage where the oil and other pollutants were collected and not allowed to run outside the building.

Analytical Results

The tables and graphs of the data collected during these two tests are given in the following appendices:

• Appendix C.	Physical Parameters (Toxicity, Turbidity, Conductivity, Color, pH)
• Appendix D.	Major Anions (Carbonate, Bicarbonate, Fluoride, Chloride, Nitrite, Nitrate, Phosphate, Sulfate)
• Appendix E.	Major Cations (Lithium, Sodium, Ammonium, Potassium, Magnesium, Calcium, Hardness)
• Appendix F.	Solids, Particle Size Distributions
• Appendix G.	Heavy Metals (Zinc, Copper)
• Appendix H.	Organics, Pesticides (COD, Semi-Volatile Organics, Pesticides)

A Wilcoxon sign-rank analysis was used to test the hypothesis that treatment did not significantly change the concentration of a given parameter. P values less than 0.10 were considered significant and led to the conclusion that treatment did significantly change the concentration of a parameter during passage through the column. However, this P value does not indicate whether or not a specific media removed the parameter of interest or leached out more of that parameter. Therefore, P values that indicate statistically significant removals are in italics in the tables. For those parameters where both the unfiltered and filtered fractions of a sample were analyzed, Wilcoxon sign-rank P values have been calculated for both sample fractions.

Toxicity

Table 40 gives the calculated P values for the Wilcoxon sign-rank analysis for the unfiltered fraction, and Table 41 gives the P values for the filtered fraction. For the unpretreated influent, which had a greater influent toxicity, the carbon-sand, zeolite-sand, and compost media had significant removals of toxicity during treatment. However, for the presettled runoff, none of the media were capable of significantly removing toxicity from the unfiltered fraction, and only carbon-sand, peat-sand, and zeolite-sand were capable of removing it from the filtered fraction.

One potential explanation for the difference in removal in the unfiltered fraction between the normal runoff and the presettled runoff is that the presettled runoff, unlike the normal runoff, only contained colloidal particles. When the particles in the influent are colloidal, they are not likely to be removed during treatment because the media do not have pores small enough to trap these particles, and any toxicity associated with these particles is not removed. The filterable fraction of the toxicity (toxicity that was due to the pollutants that were not removing by filtering through a 0.45 μm membrane filter) was removed during both tests because these media are capable of sorbing the dissolved pollutants to their surfaces.

Table 40. Wilcoxon P values for toxicity (unfiltered fraction)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.06*	0.44
Peat-sand	0.13	0.44
Zeolite-sand	*0.06*	0.38
Compost-sand	N/A*	0.16
Compost	*0.06*	N/A
Enretech-sand	N/A	0.13
Enretech	*0.09*	N/A
Forest-sand	N/A	0.38
Sand	0.06	0.50
Gunderboom fabric	0.36	0.50
EMCON fabric	0.45	0.25
ADS 4420 fabric	0.31	N/A

* N/A: this test was not performed for this medium and water combination.

Table 41. Wilcoxon P values for toxicity (filtered fraction)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	*0.06*
Peat-sand	*0.03*	*0.06*
Zeolite-sand	*0.03*	*0.06*
Compost-sand	N/A	0.45
Compost	*0.06*	N/A
Enretech-sand	N/A	0.16
Enretech	0.44	N/A
Forest-sand	N/A	0.31
Sand	0.16	0.50
Gunderboom fabric	0.06	0.56
EMCON fabric	0.03	0.56
ADS 4420 fabric	0.22	N/A

Turbidity

The calculated P values for the Wilcoxon sign-rank analysis are given in Table 42 for the unfiltered fraction and Table 43 for the filtered fraction. Except for the Gunderboom for the filtered fraction of the normal runoff, no media were capable of significantly removing turbidity either from the unfiltered or filtered fractions of either the presettled or normal runoff during treatment. For the unfiltered fraction, peat-sand, zeolite-sand, and sand significantly added turbidity to the normal influent, and the peat-sand, Enretech-sand, and Forest-sand significantly added turbidity to the presettled influent. When the influent was not presettled, removal of turbidity was inconsistent. With three exceptions, when the influent was presettled, turbidity removal was also inconsistent. Peat-sand, compost-sand, and Forest-sand media consistently added turbidity to the effluent. The added turbidity from many of the media is likely due to the flushing of colloidal particles which are too small to be trapped in the media pores and which, because of their small size, are likely part of the filtered fraction, *i.e.*, less than 0.45 μm.

Color

The calculated P values for the Wilcoxon sign-rank analysis for color for the unfiltered fraction are given in Table 44, and the P values for the filtered fraction are given in Table 45. For the presettled influent, no medium was capable of removing color from the unfiltered fraction of the influent, and only carbon-sand significantly removed color from the filtered fraction. This is likely due to the ability of the carbon to remove the organics that are causing color in the influent, and yet some of the very small pieces of carbon are washed out during treatment, and this adds color to the unfiltered fraction of the effluent. For the normal influent, the carbon-sand was the only media that was capable of significantly reducing the influent color for both the unfiltered and filtered fractions. The peat-sand, compost-sand, compost, and Enretech all added color to the unfiltered fractions of their effluents. Only for the Enretech was this added color due to particulates that were able to be removed by filtering of the effluent through a 0.45 μm filter.

Table 42. Wilcoxon P values for turbidity (unfiltered fraction)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.50	0.13
Peat-sand	0.03	0.06
Zeolite-sand	0.06	0.50
Compost-sand	N/A	0.50
Compost	0.16	N/A
Enretech-sand	N/A	0.06
Enretech	0.31	N/A
Forest-sand	N/A	0.09
Sand	0.06	0.03
Gunderboom fabric	0.31	0.50
EMCON fabric	0.50	0.16
ADS 4420 fabric	0.31	N/A

Table 43. Wilcoxon P values for turbidity (filtered fraction)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.41	0.50
Peat-sand	0.50	0.08
Zeolite-sand	0.45	0.44
Compost-sand	N/A	0.06
Compost	0.31	N/A
Enretech-sand	N/A	0.16
Enretech	0.41	N/A
Forest-sand	N/A	0.06
Sand	0.16	0.22
Gunderboom fabric	0.09	0.31
EMCON fabric	0.56	0.41
ADS 4420 fabric	0.16	N/A

Table 44. Wilcoxon P values for color (unfiltered fraction)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	0.13
Peat-sand	0.03	0.03
Zeolite-sand	0.31	0.06
Compost-sand	N/A	0.03
Compost	0.03	N/A
Enretech-sand	N/A	0.19
Enretech	0.03	N/A
Forest-sand	N/A	0.19
Sand	0.31	0.13
Gunderboom fabric	0.31	0.31
EMCON fabric	0.03	0.50
ADS 4420 fabric	0.03	N/A

Table 45. Wilcoxon P values for color (filtered fraction)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	*0.03*
Peat-sand	0.03	0.13
Zeolite-sand	0.50	0.31
Compost-sand	N/A	0.03
Compost	0.06	N/A
Enretech-sand	N/A	0.31
Enretech	0.16	N/A
Forest-sand	N/A	0.31
Sand	0.19	0.69
Gunderboom fabric	0.50	0.50
EMCON fabric	0.45	0.31
ADS 4420 fabric	0.26	N/A

Conductivity

Table 46 gives the calculated P values for the Wilcoxon sign-rank analysis for conductivity. The only media that were capable of significantly reducing conductivity were the filter fabrics for the normal influent. The other media either were incapable of removing dissolved ions from solution, or they were ion-exchange resins and leached off one ion when they adsorbed another with minimal influence on conductivity.

Table 46. Wilcoxon P values for conductivity

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.03	0.06
Peat-sand	0.31	0.03
Zeolite-sand	0.31	0.13
Compost-sand	N/A	0.03
Compost	0.03	N/A
Enretech-sand	N/A	0.38
Enretech	0.03	N/A
Forest-sand	N/A	0.13
Sand	0.16	0.31
Gunderboom fabric	*0.08*	0.16
EMCON fabric	*0.03*	0.31
ADS 4420 fabric	*0.03*	N/A

pH

The calculated P values for the sign test analysis for pH are given in Table 47. The media were considered to be removing pH problems when their effluents were closer to the neutral pH of 7 than their influents. In the bench-scale tests, the peat-sand filter tended to lower the pH of the solution while the compost-sand tended to move the pH of the solution toward neutral. In these tests, the results for all media are mixed because the influent pH is near neutral. The exception was the peat-sand that significantly lowered the pH in each test.

Table 47. Sign test P values for pH

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.19	*0.03*
Peat-sand	0.03	0.03
Zeolite-sand	0.13	0.50
Compost-sand	N/A	*0.03*
Compost	0.03	N/A
Enretech-sand	N/A	*0.03*
Enretech	0.50	N/A
Forest-sand	N/A	*0.03*
Sand	0.50	*0.03*
Gunderboom fabric	0.50	0.19
EMCON fabric	0.31	0.19
ADS 4420 fabric	*0.03*	N/A

Carbonate

The calculated P values for the Wilcoxon sign-rank test are given in Table 48. The carbon-sand and the peat-sand media significantly removed carbonate from the influent during treatment. None of the other media could consistently remove carbonate from its influents. The carbon-sand was expected to remove the carbonate because it is a sorption medium, and the peat-sand was expected to remove carbonate because the peat acts as a scavenger of carbonate. For the other sorption or ion-exchange media, the influent carbonate concentration likely was not great enough to promote significant sorption or ion-exchange.

Table 48. Wilcoxon P values for carbonate

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	*0.06*
Peat-sand	*0.06*	*0.03*
Zeolite-sand	0.50	0.31
Compost-sand	N/A	0.22
Compost	0.03	N/A
Enretech-sand	N/A	0.50
Enretech	0.22	N/A
Forest-sand	N/A	0.16
Sand	0.31	0.41
Gunderboom fabric	0.41	0.50
EMCON fabric	0.41	0.50
ADS 4420 fabric	0.31	N/A

Bicarbonate

Table 49 contains the calculated P values for the Wilcoxon sign-rank analysis for bicarbonate. The carbon-sand was the only medium that was capable of removing bicarbonate from the solution both when the influent was not presettled and when it was settled for several days prior to treatment. The peat-sand medium could only significantly remove the bicarbonate ion from the presettled runoff. The compost-sand consistently leached bicarbonate into the effluent.

Table 49. Wilcoxon P values for bicarbonate

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	*0.06*
Peat-sand	0.19	0.03
Zeolite-sand	0.03	0.16
Compost-sand	N/A	0.03
Compost	0.03	N/A
Enretech-sand	N/A	0.06
Enretech	0.03	N/A
Forest-sand	N/A	0.03
Sand	0.16	0.16
Gunderboom fabric	0.22	0.22
EMCON fabric	0.50	0.22
ADS 4420 fabric	0.41	N/A

Fluoride

The calculated P values for the Wilcoxon sign-rank analysis for fluoride are given in Table 50. No media could consistently remove fluoride from all influents. Peat-sand could only remove fluoride from the normal influent.

Table 50. Wilcoxon P values for fluoride

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.31	0.22
Peat-sand	*0.03*	0.31
Zeolite-sand	0.41	0.16
Compost-sand	N/A	0.50
Compost	0.03	N/A
Enretech-sand	N/A	0.19
Enretech	0.41	N/A
Forest-sand	N/A	0.50
Sand	0.50	0.50
Gunderboom fabric	0.03	0.56
EMCON fabric	0.19	0.09
ADS 4420 fabric	0.31	N/A

Chloride

Table 51 gives the calculated P values for the Wilcoxon sign-rank analysis for chloride. The carbon-sand medium consistently leached chloride into its effluent. The peat-sand and zeolite-sand media were only capable of removing chloride from presettled influent. The other media did not significantly and consistently remove chloride from or add chloride to the solution during treatment.

Table 51. Wilcoxon P values for chloride

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.03	0.03
Peat-sand	0.03	*0.03*
Zeolite-sand	0.22	*0.03*
Compost-sand	N/A	0.16
Compost	0.09	N/A
Enretech-sand	N/A	0.22
Enretech	0.03	N/A
Forest-sand	N/A	0.50
Sand	0.50	0.16
Gunderboom fabric	0.31	0.22
EMCON fabric	0.22	0.50
ADS 4420 fabric	0.31	N/A

Nitrate

The calculated P values for the Wilcoxon sign-rank analysis are given in Table 52. Carbon-sand is the only medium that consistently removed nitrate during treatment. The other media were inconsistent at removing nitrate from solution. In many areas, nitrate is considered a problem pollutant that must be controlled because excess nitrate in a drinking water source can lead to methemoglobinemia in infants. Excess nitrate also may cause eutrophication in a nitrogen-limited water body. For those areas where nitrate must be controlled, the carbon-sand is the only medium that will consistently remove it from solution. In order to remove nitrate from the influent with the other media, a zone of denitrification must be established at the bottom of the media or in a subsequent chamber.

Table 52. Wilcoxon P values for nitrate

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.06*	*0.06*
Peat-sand	0.13	0.56
Zeolite-sand	0.06	0.56
Compost-sand	N/A	0.50
Compost	0.03	N/A
Enretech-sand	N/A	0.13
Enretech	0.19	N/A
Forest-sand	N/A	0.19
Sand	0.50	0.56
Gunderboom fabric	0.44	0.03
EMCON fabric	0.22	0.13
ADS 4420 fabric	0.06	N/A

Sulfate

Table 53 gives the calculated P values for the Wilcoxon sign-rank analysis for sulfate. No media consistently removed sulfate from solution. For the carbon-sand medium, sulfate is one of the major ions that is exchanged when other ions are removed from solution.

Table 53. Wilcoxon P values for sulfate

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.03	0.03
Peat-sand	0.03	*0.06*
Zeolite-sand	0.06	0.41
Compost-sand	N/A	0.50
Compost	0.09	N/A
Enretech-sand	N/A	0.21
Enretech	0.03	N/A
Forest-sand	N/A	0.31
Sand	0.50	0.16
Gunderboom fabric	0.31	0.50
EMCON fabric	0.41	0.41
ADS 4420 fabric	0.41	N/A

Hardness

The calculated P values for the Wilcoxon sign-rank analysis for hardness are given in Table 54. Hardness is a measure of the divalent cation concentration in the water, and it is primarily composed of calcium and magnesium. Peat-sand is the only medium that effectively removed hardness from the influent because it is lacking in calcium and scavenged calcium from solution. Compost increases the hardness of the solution during treatment, indicating that it is leaching divalent cations into the water.

Table 54. Wilcoxon P values for hardness

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.27	0.45
Peat-sand	*0.03*	*0.03*
Zeolite-sand	0.41	0.31
Compost-sand	N/A	0.03
Compost	0.03	N/A
Enretech-sand	N/A	0.22
Enretech	0.22	N/A
Forest-sand	N/A	0.22
Sand	0.31	0.44
Gunderboom fabric	0.45	0.31
EMCON fabric	0.22	0.13
ADS 4420 fabric	0.41	N/A

Sodium

Table 55 contains the calculated P values for the Wilcoxon sign-rank analysis for sodium. Only the ADS 4420 fabric significantly removed sodium from the solution for the unpretreated influent. The other media were inconsistent at removing sodium from the solution or, like the carbon-sand for presettled runoff, leached sodium into the water.

Table 55. Wilcoxon P values for sodium

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.22	0.03
Peat-sand	0.03	0.50
Zeolite-sand	0.09	0.03
Compost-sand	N/A	0.31
Compost	0.03	N/A
Enretech-sand	N/A	0.06
Enretech	0.03	N/A
Forest-sand	N/A	0.03
Sand	0.56	0.41
Gunderboom fabric	0.16	0.50
EMCON fabric	0.41	0.50
ADS 4420 fabric	*0.03*	N/A

Ammonium

The calculated P values for the Wilcoxon sign-rank analysis for ammonium are given in Table 56. No medium was capable of consistently removing ammonium from solution, including the zeolite that was designed for ammonia removal. The Enretech was capable of removing ammonium from the normal influent, yet the Enretech-sand medium was not capable of removing ammonium from the presettled influent.

Table 56. Wilcoxon P values for ammonium

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.56	0.16
Peat-sand	0.31	0.31
Zeolite-sand	0.44	0.22
Compost-sand	N/A	0.31
Compost	0.44	N/A
Enretech-sand	N/A	0.50
Enretech	*0.06*	N/A
Forest-sand	N/A	0.50
Sand	0.31	0.41
Gunderboom fabric	0.44	0.16
EMCON fabric	0.31	0.31
ADS 4420 fabric	0.44	N/A

Potassium

The calculated P values for the Wilcoxon sign-rank analysis for potassium are given in Table 57. The carbon-sand and zeolite-sand media were capable of significantly removing potassium from solution. The peat-sand and compost-sand added potassium during treatment due to their ion-exchange capabilities. None of the other media was consistent at either removing potassium from or leaching potassium into the water during treatment.

Table 57. Wilcoxon P values for potassium

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.06*	*0.03*
Peat-sand	0.03	0.03
Zeolite-sand	*0.03*	*0.03*
Compost-sand	N/A	0.03
Compost	0.03	N/A
Enretech-sand	N/A	0.06
Enretech	0.16	N/A
Forest-sand	N/A	0.03
Sand	0.41	0.31
Gunderboom fabric	0.16	0.13
EMCON fabric	0.31	0.31
ADS 4420 fabric	0.31	N/A

Magnesium

Table 58 contains the calculated P values from the Wilcoxon sign-rank analysis for magnesium. Compost-sand was the only medium that consistently leached magnesium into its effluent. No medium was capable of significantly removing magnesium from the runoff during treatment.

Table 58. Wilcoxon P values for magnesium

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.06	0.45
Peat-sand	0.31	0.31
Zeolite-sand	0.03	0.22
Compost-sand	N/A	0.03
Compost	0.03	N/A
Enretech-sand	N/A	0.16
Enretech	0.16	N/A
Forest-sand	N/A	0.50
Sand	0.41	0.50
Gunderboom fabric	0.31	0.16
EMCON fabric	0.16	0.50
ADS 4420 fabric	0.31	N/A

Calcium

The calculated P values for the Wilcoxon sign-rank analyses for calcium are given in Table 59. Peat is calcium-poor, and, therefore, the peat-sand medium was expected to remove calcium from the influent during treatment. It was the only medium capable of regularly removing calcium from solution. The zeolite-sand significantly removed calcium from the influent when the runoff was presettled prior to treatment, yet it leached calcium when the influent was not presettled.

Table 59. Wilcoxon P values for calcium

Filtration media	Unpretreated influent	PreSettled influent
Carbon-sand	0.22	0.22
Peat-sand	*0.03*	*0.03*
Zeolite-sand	0.09	*0.03*
Compost-sand	N/A	0.16
Compost	0.03	N/A
Enretech-sand	N/A	0.16
Enretech	0.03	N/A
Forest-sand	N/A	0.41
Sand	0.56	0.06
Gunderboom fabric	0.16	0.09
EMCON fabric	0.41	0.31
ADS 4420 fabric	0.03	N/A

Solids

Table 60 gives the calculated P values for the Wilcoxon sign-rank analysis for total solids; Table 61 gives the P values for dissolved solids; and Table 62 gives the P values for suspended solids. The peat-sand was the only medium capable of removing total solids from the presettled influent when the influent concentration of total solids was small. The sand, Gunderboom, and EMCON were capable of significantly removing total solids from the normal influent, indicating that their best removal efficiencies occur when the total solids in the influent are fairly high, *i.e.*, the runoff has not been allowed to settle for several days. Only peat-sand and the EMCON fabric were capable of significant removal of total dissolved solids with the presettled influent. No other media or fabric was capable of any significant removal of dissolved solids for any test. Only the four media, carbon-sand, zeolite-sand, sand, and Gunderboom, were capable of removing suspended solids from the influent and then only when the influent concentration was high, such as when the runoff was not presettled.

Table 60. Wilcoxon P values for total solids

Filtration media	Unpretreated influent	PreSettled influent
Carbon-sand	0.22	0.50
Peat-sand	0.16	*0.06*
Zeolite-sand	0.45	0.63
Compost-sand	N/A	0.06
Compost	0.03	N/A
Enretech-sand	N/A	0.50
Enretech	0.06	N/A
Forest-sand	N/A	0.50
Sand	*0.06*	0.45
Gunderboom fabric	*0.09*	0.22
EMCON fabric	*0.06*	0.41
ADS 4420 fabric	0.13	N/A

Table 61. Wilcoxon P values for total dissolved solids

Filtration media	Unpretreated influent	PreSettled influent
Carbon-sand	0.03	0.50
Peat-sand	0.16	*0.03*
Zeolite-sand	0.05	0.03
Compost-sand	N/A	0.06
Compost	0.03	N/A
Enretech-sand	N/A	0.16
Enretech	0.03	N/A
Forest-sand	N/A	0.50
Sand	0.41	0.44
Gunderboom fabric	0.27	0.13
EMCON fabric	0.41	*0.03*
ADS 4420 fabric	0.41	N/A

Table 62. Wilcoxon P values for total suspended solids

Filtration media	Unpretreated influent	PreSettled influent
Carbon-sand	*0.06*	0.19
Peat-sand	0.50	0.44
Zeolite-sand	*0.09*	0.50
Compost-sand	N/A	0.16
Compost	0.50	N/A
Enretech-sand	N/A	0.31
Enretech	0.50	N/A
Forest-sand	N/A	0.41
Sand	*0.03*	0.41
Gunderboom fabric	0.13	0.41
EMCON fabric	*0.06*	0.31
ADS 4420 fabric	*0.06*	N/A

Volatile Solids

The calculated P values for the Wilcoxon sign-rank analysis for volatile total solids are given in Table 63; for volatile dissolved solids, Table 64; and for volatile suspended solids, Table 65. When the runoff is allowed to settle for several days prior to treatment, the Enretech-sand and sand media were capable of removing volatile total solids from the influent. For the same influent, however, the compost-sand medium added volatile total solids during treatment, likely because pieces of the compost were leaching from the media. None of the media were capable of removing either volatile dissolved solids or volatile suspended solids from presettled influent. For the normal runoff, where the influent concentration was greater, carbon-sand, zeolite-sand, sand, Gunderboom, and ADS 4420 were capable of removing volatile total solids. Again the compost-sand medium, as well as the peat-sand medium, leached organics from the filter into the effluent. Carbon-sand was the only medium capable of removing both volatile dissolved solids and volatile suspended solids from the normal runoff. The zeolite-sand could significantly remove only volatile suspended solids from the normal runoff. The compost and the peat-sand media both consistently added volatile dissolved and suspended solids to the runoff during treatment.

Table 63. Wilcoxon P values for volatile total solids

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	0.16
Peat-sand	0.09	0.27
Zeolite-sand	*0.03*	0.63
Compost-sand	N/A	0.03
Compost	0.03	N/A
Enretech-sand	N/A	*0.09*
Enretech	0.06	N/A
Forest-sand	N/A	0.16
Sand	*0.03*	*0.06*
Gunderboom fabric	*0.06*	0.22
EMCON fabric	0.16	0.31
ADS 4420 fabric	*0.03*	N/A

Table 64. Wilcoxon P values for volatile dissolved solids

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	0.38
Peat-sand	0.06	0.31
Zeolite-sand	0.31	0.45
Compost-sand	N/A	0.06
Compost	0.03	N/A
Enretech-sand	N/A	0.50
Enretech	0.03	N/A
Forest-sand	N/A	0.22
Sand	0.31	0.37
Gunderboom fabric	0.31	0.44
EMCON fabric	0.45	0.25
ADS 4420 fabric	0.16	N/A

Table 65. Wilcoxon P values for volatile suspended solids

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	0.45
Peat-sand	0.27	0.22
Zeolite-sand	*0.09*	0.45
Compost-sand	N/A	0.45
Compost	0.09	N/A
Enretech-sand	N/A	0.22
Enretech	0.55	N/A
Forest-sand	N/A	0.16
Sand	0.13	0.16
Gunderboom fabric	0.55	0.41
EMCON fabric	0.16	0.44
ADS 4420 fabric	0.45	N/A

Particle Size Distribution (1 to 2 μm)

The calculated P values for the Wilcoxon sign-rank analysis for particle size distribution (1 to 2 μm) are given in Table 66. None of the media were capable of removing these small-sized particles from solution during treatment. In fact, the peat-sand, zeolite-sand, compost-sand, Enretech-sand, Forest-sand, and sand media had some of their finer particles washed out of the media and into the effluent. These filters were not expected to effectively remove particles in this size range because this is their approximate pore size.

Table 66. Wilcoxon P values for PSD (1 to 2 μm)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.16	0.16
Peat-sand	0.03	0.03
Zeolite-sand	0.06	0.03
Compost-sand	N/A	0.03
Compost	0.31	N/A
Enretech-sand	N/A	0.03
Enretech	0.03	N/A
Forest-sand	N/A	0.06
Sand	0.22	0.03
Gunderboom fabric	0.41	0.31
EMCON fabric	0.16	0.16
ADS 4420 fabric	0.08	N/A

Particle Size Distribution (4 to 5 μm)

Table 67 gives the calculated P values for the Wilcoxon sign-rank analysis for the particle size distribution between 4 and 5 μm. When the runoff is presettled, no medium is capable of significantly removing particles in this size range. However, when the runoff was not presettled prior to filtration, the carbon-sand and sand media were able to significantly remove 4 to 5 μm particles from their influents. The peat-sand and the compost media washed particles of this size range out of the filter into their effluents. The zeolite-sand, Enretech-sand, and the ADS 4420 also may add particles of this size range to the solution, but this addition is not consistent when the runoff has been presettled.

Table 67. Wilcoxon P values for PSD (4 to 5 μm)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.09*	0.16
Peat-sand	0.03	0.06
Zeolite-sand	0.09	0.31
Compost-sand	N/A	0.09
Compost	0.16	N/A
Enretech-sand	N/A	0.31
Enretech	0.06	N/A
Forest-sand	N/A	0.31
Sand	*0.06*	0.31
Gunderboom fabric	0.16	0.41
EMCON fabric	0.22	0.22
ADS 4420 fabric	0.03	N/A

Particle Size Distribution (11 to 12.5 μm)

The calculated P values for the Wilcoxon sign-rank analysis for the particle size distribution in the 11 to 12.5 μm range are given in Table 68. For the presettled runoff, the carbon-sand, Gunderboom, and EMCON produced statistically significant reductions of particles in this size range; however, the carbon-sand was the only medium which was capable of producing a removal efficiency of greater than ten percent. When the influent was not presettled, the carbon-sand, zeolite-sand, compost, and sand media were capable of producing a significant removal of particles in this size range.

Particle Size Distribution (1 to 128 μm)

Table 69 gives the calculated P values for the Wilcoxon sign-rank analysis for particle size distribution across the range of 1 to 128 μm. When the runoff was not presettled, carbon-sand, peat-sand, zeolite-sand, and sand were all capable of significant removal of particles from this size range (measured as cumulative volume occupied by particles per milliliter of solution). However, when the influent had settled for several days, none of the media were capable of significantly removing particles during treatment.

Table 68. Wilcoxon P values for PSD (11 to 12.5 μm)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.03*	0.03
Peat-sand	0.41	0.03
Zeolite-sand	*0.03*	0.31
Compost-sand	N/A	0.06
Compost	*0.09*	N/A
Enretech-sand	N/A	0.50
Enretech	0.31	N/A
Forest-sand	N/A	0.16
Sand	*0.03*	0.41
Gunderboom fabric	0.16	*0.06*
EMCON fabric	0.41	*0.06*
ADS 4420 fabric	0.41	N/A

Table 69. Wilcoxon P values for PSD (1 to 128 μm)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.09*	0.16
Peat-sand	*0.03*	0.06
Zeolite-sand	*0.09*	0.31
Compost-sand	N/A	0.09
Compost	0.16	N/A
Enretech-sand	N/A	0.31
Enretech	0.06	N/A
Forest-sand	N/A	0.31
Sand	*0.06*	0.31
Gunderboom fabric	0.16	0.41
EMCON fabric	0.22	0.22
ADS 4420 fabric	0.03	N/A

Zinc

The calculated P values for the Wilcoxon sign-rank analysis for zinc, unfiltered and filtered fraction, are given in Table 70. All of the media were capable of significantly removing zinc from both the unfiltered and filtered fraction of the influent during treatment. Neither of the filter fabrics could remove the zinc during treatment, which was expected since zinc tends to sorb to small particles in solution. Zinc sorption to small particles enhances its ability to pass through the filters and the fabrics.

Table 70. Wilcoxon P values for zinc for presettled influent

Filtration media	Unfiltered fraction	Filtered fraction
Carbon-sand	*0.03*	*0.06*
Peat-sand	*0.03*	*0.03*
Zeolite-sand	*0.03*	*0.03*
Compost-sand	*0.03*	*0.03*
Enretech-sand	*0.03*	*0.03*
Forest-sand	*0.03*	*0.03*
Sand	*0.03*	*0.03*
Gunderboom fabric	0.41	0.31
EMCON fabric	0.50	0.50

Copper

The calculated P values for the Wilcoxon sign-rank analysis for copper, unfiltered and filtered fractions, are given in Table 71. No media were capable of removing copper from the runoff, possibly because the influent concentrations were low and the runoff did not have sufficient contact time with the media for sorption to occur. The Forest-sand media added particulate copper to the runoff during treatment, indicating that copper was leaching from the media.

Table 71. Wilcoxon P values for copper for presettled influent

Filtration media	Unfiltered fraction	Filtered fraction
Carbon-sand	0.50	0.41
Peat-sand	0.31	0.50
Zeolite-sand	0.50	0.22
Compost-sand	0.31	0.22
Enretech-sand	0.41	0.50
Forest-sand	0.06	0.41
Sand	0.16	0.41
Gunderboom fabric	0.41	0.50
EMCON fabric	0.41	0.50

Chemical Oxygen Demand (COD)

Table 72 gives the calculated P values for the Wilcoxon sign-rank analysis for COD for the unfiltered fraction, and Table 73 gives the P values for the filtered fraction. Only the carbon-sand medium was capable of removing dissolved chemical oxygen demand from both the presettled and normal runoffs. Carbon-sand, Gunderboom and EMCON significantly removed particulate COD from the presettled runoff. No significant removals occurred during treatment of the normal influent.

Table 72. Wilcoxon P values for chemical oxygen demand (unfiltered fraction)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	0.13	*0.03*
Peat-sand	0.06	0.50
Zeolite-sand	0.50	0.22
Compost-sand	N/A	0.03
Compost	0.09	N/A
Enretech-sand	N/A	0.31
Enretech	0.06	N/A
Forest-sand	N/A	0.31
Sand	0.50	0.25
Gunderboom fabric	0.50	*0.03*
EMCON fabric	0.50	*0.09*
ADS 4420 fabric	0.16	N/A

Table 73. Wilcoxon P values for chemical oxygen demand (filtered fraction)

Filtration media	Normal influent	PreSettled influent
Carbon-sand	*0.06*	*0.03*
Peat-sand	0.03	0.31
Zeolite-sand	0.31	0.31
Compost-sand	N/A	0.03
Compost	0.03	N/A
Enretech-sand	N/A	0.31
Enretech	0.06	N/A
Forest-sand	N/A	0.22
Sand	0.06	0.19
Gunderboom fabric	0.16	0.22
EMCON fabric	0.31	0.19
ADS 4420 fabric	0.09	N/A

Semi-Volatile Organics

The semi-volatile organics were only analyzed on the effluents from the media that received presettled runoff. Because this runoff was presettled and the particulate loading was much smaller than the loading likely would be in normal runoff, very few of the organics of interest were found in both the settled runoff influent and effluent. A Wilcoxon sign-rank analysis was performed for the five organics which were detected in at least ten percent of the samples: 2,4-dinitrophenol, 2-methyl-4,6-dinitrophenol, di-n-butylphthalate, bis(2-ethylhexyl) phthalate, and pentachlorophenol. The calculated P values for the Wilcoxon sign-rank analysis are given in Table 74. For the semi-volatiles only, the P value used for significance was 0.15. This value was chosen because not all of the storms had detectable concentrations of a semi-volatile organic in the influent and a P of less than 0.15 meant that the media had to measurably alter, in one direction only, the concentration of that organic for all storm events in which that compound was detected in either the influent or effluent. The variability of the data causes the conclusions reached to be tentative, and in need of further study, especially since phthalate contamination from plastics is a known problem in environmental analysis. Based upon the literature, carbon-sand would be expected to remove most of these organics from solution. However, it was only capable of removing 2,4-dinitrophenol and bis(2-ethylhexyl) phthalate from solution consistently. Peat-sand was capable of removing three of the five organics: 2,4-dinitrophenol, di-n-butyl phthalate, and bis(2-ethylhexyl) phthalate. The zeolite-sand and the sand media could only remove two organics: bis(2-ethylhexyl) phthalate and pentachlorophenol. The Enretech-sand also could only remove two organics: 2,4-dinitrophenol and pentachlorophenol. The Forest-sand medium could only remove the pentachlorophenol. The EMCON fabric could not remove any of the detected semi-volatile organics while the Gunderboom fabric could remove the 2,4-dinitrophenol and di-n-butyl phthalate. The influent concentration of many of these compounds was very low. The sorption media may have been able to remove more compounds or could have had higher removal efficiencies if the influent concentration of these compounds had been higher, *i.e.*, if the influent concentration was significantly above the threshold concentration at which no detectable sorption will occur.

Table 74. Wilcoxon P values for semi-volatile organics for presettled influent

Filtration media	2,4-Di-nitrophenol	2-Methyl-4,6-dinitrophenol	Di-n-butyl-phthalate	Bis(2-ethyl-hexyl) phthalate	Pentachloro-phenol
Carbon-sand	*0.13*	0.38	0.63	*0.13*	0.44
Peat-sand	*0.13*	0.25	*0.13*	*0.13*	0.19
Zeolite-sand	0.25	0.38	0.38	*0.13*	*0.06*
Compost-sand	0.38	0.50	0.38	0.25	0.31
Enretech-sand	*0.13*	0.63	0.38	0.38	*0.06*
Forest-sand	0.38	0.25	0.38	0.25	*0.06*
Sand	0.31	0.25	0.25	*0.13*	*0.06*
Gunderboom fabric	*0.13*	0.25	*0.13*	0.44	0.19
EMCON fabric	0.06	0.56	0.19	0.31	0.56

Pesticides

Like the semi-volatile organics, not all of the pesticides analyzed were detected in every sample. The pesticides detected in more than 20 percent of the samples were dieldrin and 4,4'-DDT. The calculated P values for the Wilcoxon sign-rank analysis for these two compounds are given in Table 75. Only peat-sand was capable of significantly removing dieldrin during treatment while none of the media were capable of significantly removing 4,4'-DDT during treatment. The Forest-sand medium, containing the kenaf-based agrofiber, leached lindane (gamma-BHC) into its effluent. Effluent concentrations of lindane for this filter ranged from 0.03 to 0.6 mg/L for the three storm events in which it was detected. None of the storm events had any detectable lindane in the influent runoff before treatment; therefore, the lindane must have originated from the agrofiber.

Table 75. Wilcoxon P values for pesticides for presettled influent

Filtration media	Dieldrin	4,4'-DDT
Carbon-sand	0.31	0.31
Peat-sand	*0.06*	0.16
Zeolite-sand	0.56	0.13
Compost-sand	0.56	0.63
Enretech-sand	0.31	0.31
Forest-sand	0.31	0.06
Sand	0.41	0.38
Gunderboom fabric	0.41	0.50
EMCON fabric	0.22	0.16

Other Observations

Pretreatment of the water by settling for a minimum of three days to significantly reduce the suspended solids increased the water volume that could be treated before clogging. However, it generally decreased the amount of sediment needed to clog the media columns. The settling pretreatment removed all of the faster-sinking particles (generally the largest particles), leaving the smaller and less dense particles in the solution. These particles appeared to have a greater detrimental effect on the flow rate through the media than the larger and denser particles.

The activated carbon showed the greatest pollutant concentration reductions compared to the other media. The removal capability seemed to slightly decrease with time; however, there was no indication that chemical breakthrough had been achieved for this medium. The other media did not show as great an adsorption ability as the activated carbon. The zeolite-sand, Enretech-sand, and Forest-sand filters showed limited removal ability. The compost-sand and peat-sand media showed significant increases in organics in their effluents due to the natural humics that are washed off the media during treatment.

Table 76 summarizes the results of the long-term tests by giving average percent removals during treatment for those media that had significant concentration reductions of a given parameter. The results are presented for each parameter for the presettled influent first and then the normal influent that was not presettled. An entry of "*" means that the media made no significant reductions in that parameter during treatment. Parameters that are not listed had no media that caused a significant removal during treatment.

The Enretech-sand, Forest-sand, and the filter fabrics had the poorest removal efficiencies of all the media. They were only capable of significantly removing between three and five parameters. The compost-sand also was not effective at removing many constituents from the influent. The zeolite-sand medium was only slightly better than the sand medium for the number of potential pollutants that it removed. The two best media, based on the number of parameters they were capable of significantly removing, were the carbon-sand and the peat-sand. Carbon-sand's advantage is that it does not have as many undesirable side effects, such as adding suspended solids and color to its effluent.

Table 76. Average percent removal by media

	Carbon-sand	Peat-sand	Zeolite-sand	Compost-sand	Enretech-sand	Forest-sand	Sand	Gunderboom	EMCON
Physical characterization									
Toxicity (U)	*/100	*/*	*/87	*/100	*/<10	*	*/*	*/*	*/*
Toxicity (F)	83/95	63/61	100/45	*/71	*/*	*	*/*	*/*	*/*
Color (U)	*/60	*/*	*/*	*/*	*/*	*	*/*	*/*	*/*
Color (F)	26/64	*/*	*/*	*/*	*/*	*	*/*	*/*	*/*
Major anions									
Carbonate	47/69	100/87	*/*	*/*	*/*	*	*/*	*/*	*/*
Bicarbonate	23/44	*/*	*/*	*/*	*/*	*	*/*	*/*	*/*
Fluoride	*/*	*/<10	*/*	*/*	*/*	*	*/*	*/*	*/*
Chloride	*/*	17/*	7/*	*/*	*/*	*	*/*	*/*	*/*
Nitrate	97/94	*/*	*/*	*/*	*/*	*	*/*	*/*	*/*
Sulfate	*/*	5/*	*/*	*/*	*/*	*	*/*	*/*	*/*
Major cations and hardness									
Hardness	*/*	52/59	*/*	*/*	*/*	*	*/*	*/*	*/*
Potassium	15/46	*/*	39/35	*/*	*/*	*	*/*	*/*	*/*
Calcium	*/*	88/75	17/*	*/*	*/*	*	*/*	*/*	*
Solids and particle size distribution (PSD)									
Total solids	*/*	27/*	*/*	*/*	*/*	*	*/11	*/10	*/5
Dissolved solids	*/*	45/*	*/*	*/*	*/*	*	*/*	*/*	*/*
Suspended solids	*/52	*/*	*/45	*/*	*/*	*	*/74	*/31	*/23
Volatile solids	*/71	*/*	*/17	*/*	20/*	*	8/20	*/<5	*/*
VDS	*/59	*/*	*/*	*/*	*/*	*	*/*	*/*	*/*
VSS	*/85	*/*	*/33	*/*	*/*	*	*/*	*/*	*/*
Cum. PSD	*/81	*/28	*/58	*/27	*/*	*	*/65	*/*	*/*
Metals									
Zinc (U)	76	70	73	76	66	77	77	*	*
Zinc (F)	48	58	62	82	77	81	81	*	*
Chemical oxygen demand; semi-volatile organics; and pesticides									
COD (U)	96/*	*/*	*/*	*/*	*/*	*	*/*	55/*	22/*
COD (F)	85/59	*/*	*/*	*/*	*/*	*	*/*	*/*	*/*
2,4-DNP	43	36	*	*	30	*	*	79	*
DnBP	*	66	*	*	*	*	*	76	*
B(2eh)P	90	23	82	*	*	*	94	*	*
PCP	*	*	79	*	87	92	100	*	*
Dieldrin	*	68	*	*	*	*	*	*	*

NOTES:	*	No significant removal occurred.	/	Divider between long term tests. PreSettled/unpretreated average removal reported in table.
	U	Unfiltered fraction of runoff.	F	Filtered fraction of runoff.
	VDS	Volatile dissolved solids.	VSS	Volatile suspended solids.
	PSD	Particle size distribution (cumulative 1 to 128 μm).	COD	Chemical oxygen demand.
	2,4-DNP	2,4-Dinitrophenol.	DnBP	Di-n-butyl phthalate.
	B(2eh)P	Bis(2-ethylhexyl) phthalate.	PCP	Pentachlorophenol.

Chapter 5
Conclusions: Design of Stormwater Filters

The information obtained during this research can be used to develop guidelines for stormwater treatment using filtration, especially when used in conjunction with reported information in the literature. The design of a stormwater filter needs to be divided into two phases. The first phase is the selection of the filtration media to achieve the desired pollutant goals. The second phase is the sizing of the filter to achieve the desired run time before the media must be replaced.

The main objective of this research was to monitor a variety of filtration media to determine their pollutant removal capabilities. However, it soon became apparent that the filters were more limited by clogging caused by suspended solids in stormwater runoff. The clogging occurred long before reductions in their pollutant removal capabilities could be identified. Therefore, measurements in filter run times, including flow rates and clogging parameters, were added to the research activities. However, the small-scale filter set-ups used for the pollutant removal measurements probably under-predicted the actual run times that could be achieved under full-scale applications. Even with increased filter depth utilization and better drying between storms that may be achieved with full-scale applications, pretreatment of the stormwater so the suspended solids content is about 10 mg/L is probably necessary in order to take advantage of the pollutant retention capabilities of most of the media. This level of pretreatment, however, may make further stormwater runoff control unnecessary. Of course, it may be more cost-effective to consider shortened filter run times, without pretreatment, or pretreatment of only a few minutes (thus, not using all the pollutant retention capacities of the media).

Selection of Filtration Media for Pollutant Removal Capabilities

The selection of the filter media needs to be based on the desired pollutant removal performance and the associated conditions, such as land use. If the selection criterion were suspended solids removal for stormwater that was not pretreated (most common), then the filtration media would be ranked according to the following (bench-scale testing results, which may differ, reported in parentheses):

- >50% reduction for suspended solids: Sand and carbon-sand (both long- term and bench-scale testing indicated these high suspended solids reductions)
- 20-50%: Zeolite-sand and filter fabrics (long-term testing; bench scale removals: >90% zeolite-sand, <10% filter fabrics)
- <10%: Peat-sand and Enretech-sand (long term testing; bench scale removals: 80-90% peat-sand, >90% Enretech-sand)

As can be seen by the comparison of the long-term testing with the bench-scale results for the neutral pH, moderate ionic strength condition, results will vary depending on the quality of the influent, i.e., particle size distribution of influent. Influents with a greater concentration of larger particles are likely to have better removal efficiencies than have been found in these tests. The results of the neutral pH bench-scale tests indicate that the dissolved solids in runoff may improve the ability of the media to trap and retain suspended solids. It also would be expected that the longer the filter is in service, *i.e.*, run nearer to breakthrough or clogging, the greater the percentage of the influent suspended solids that will be removed from solution and retained by the media.

If the filter media were being selected based upon a wider range of pollutants for normal stormwater that is not presettled, then the ranking, based on the number of pollutants that would be removed during filtration, would be as follows (with additional comments pertaining to degradation by other pollutants in parentheses):

- Carbon-sand (minimal to no degradation of effluent)

- Peat-sand (degradation of effluent with higher turbidity, color, COD, small particles)
- Zeolite-sand and sand (minimal degradation of effluent)
- Enretech-sand (minimal degradation of effluent)
- Compost-sand (degradation of effluent with higher color, COD, solids)
- Forest-sand and filter fabrics (minimal degradation of effluent)

All of the filters perform better after they are aged because they have the potential to build up a biofilm that will aid in permanent retention of pollutants. Aged filters also have fewer small particles that may be available to be washed out of the media during filtration.

Potential problems with the media were outlined in Chapter 4 for each parameter measured. However, when selecting a media, the designer must remember that most of these media are ion-exchange materials. This means that when ions are removed from solution by a filter medium, then other ions are released into solution. In most instances, these exchangeable ions are not a problem in receiving waters, but the designer should know what is being added to the water. For this activated carbon, the exchangeable ion is mostly sulfate; while for the compost, it is usually potassium. The zeolite appears to exchange sodium and some divalent cations (increasing hardness) for the ions it sorbs.

Another potential problem caused by stormwaters entering receiving waters is eutrophication due to the loading of inorganic nitrogen, phosphate, or both into the water. Only the activated carbon was capable of effectively removing nitrate from the runoff. Phosphates, which are a greater problem in most areas of the country, were not present in the runoff that was tested, and, therefore, no judgments can be made about the ability of these media to remove phosphate from the water.

Presettling of the stormwater was conducted to reduce the solids loadings on the filters to increase the run times before clogging (as described below) in order to take advantage of the chemical retention capabilities of the filters. The settling reduced the stormwater suspended solids concentrations to about 10 mg/L, with about 90% of the particles being less than 10 μm in size (by volume and therefore assumed by mass). The unpretreated stormwater had a suspended solids concentration of approximately 30 mg/L, with about 90% of the particles being less than 50 μm. The presettling also reduced the other stormwater pollutants (for example, color and turbidity by about 50%, and COD by about 90%). This presettling was similar to what would occur in a well-designed and operated wet detention pond or in the settling chamber of the Multi-Chamber Treatment Train. This presettling had a significant effect on filter performance, as noted, and the rankings would be as follows, using a wide range of stormwater pollutants. Since the suspended solids concentration is not likely to be further reduced by the filters, it by itself would no longer be a suitable criterion for selecting a medium.

- Carbon-sand (minimal effluent degradation)
- Peat-sand (degradation of effluent color, turbidity, pH)
- Zeolite-sand, Enretech-sand, Forest-sand, sand (min. effluent degradation)
- Compost-sand (minimal removal, color degradation)
- Filter fabrics (minimal improvement or degradation)

Obviously, the stormwater control objectives and options will significantly affect the selection of the media. This is most evident with the compost media. If suspended solids removal alone is the criterion, and if a slight color increase is acceptable, then the compost filter is a good choice for an unpretreated stormwater. However, if the filter is to be used after significant pretreatment, the compost filter then is not a very good choice.

The stormwater control objectives may dictate a combination of filter media similar to that employed in this research for the bench-scale and long-term filter tests. The peat-sand and the compost-sand media provide excellent removal for some pollutants but they add some potentially undesirable constituents to the water. However, a three-layer filter may be a consideration (sand as the bottom layer, activated carbon-sand as the middle layer, and compost-sand or peat-sand as the top layer). By sandwiching the activated carbon-sand layer between the compost or peat and the sand layer, some color removal from the organic media leachate may be possible. Also, the dual layer may provide additional turbidity and solids removal. The cost of activated carbon may prevent it from being used as the selected medium; however, by using a trilayer filter setup, the cost of a small activated carbon layer would be minimal.

Operational considerations also may dictate the choice of media. For installations with no pretreatment, the addition of a filter fabric on the top layer may be desirable. This filter fabric will trap the large particles and postpone clogging, and it will evenly distribute the runoff across the filter and prevent bypassing of parts of the filter. The use of a filter fabric should noticeably increase the life of the filter because the filter fabric can be removed easily and cleaned. Cleaning the top layer of the filter itself would be significantly more work for the filter owner. A filter fabric top layer is recommended even if the water is presettled to facilitate flow distribution across the media.

The following list is a summary of the likely significant reductions in concentration for the filters. This list also includes the minimum expected effluent concentrations for suspended solids, color, and turbidity.

Sand

The sand filter will provide moderate to good removal for many pollutants that are associated with particulates and has a greater removal efficiency when the stormwater is not presettled. When the influent was presettled, significant removal occurred only for volatile total solids, zinc, and two of the organics, bis(2-ethylhexyl) phthalate and pentachlorophenol. Influent pH and ionic strength, acting independently, can affect both the final effluent quality and removal efficiency with the highest effluent zinc, suspended solids, and COD concentrations occurring when the influent pH was low and the influent salt concentration was high.

For the sand filter, the level of control available for any parameter is associated with the retention of suspended solids and the associated particulate fractions of pollutants. The sand filter can flush out previously captured pollutants until the filter is aged and a biofilm is grown that will more permanently retain pollutants. When the water is presettled, little removal benefit occurs. The likely minimum effluent concentrations are as follows: 10 mg/L for suspended solids, 50 HACH color units, and 10 NTU for turbidity.

Peat-sand

The peat-sand filter provides moderate to excellent pollutant control for most pollutants in both normal and presettled stormwater runoff. In general, the best average removal efficiency occurred for presettled runoff. The disadvantage of the peat-sand filter is the increase in turbidity and color in the effluent and the reduction in the pH of approximately one to two pH units. The influent pH and ionic strength will control both the effluent quality and removal efficiency. Low influent pH causes a poorer effluent quality for hardness, zinc, copper, and color. High influent pH leads to higher effluent COD concentrations. The influent ionic strength controls the effluent turbidity and zinc.

Unlike the sand filter, the peat-sand is capable of removing pollutants immediately by either sorption or ion-exchange. Presettling of the runoff prior to filtration appears to improve the removal ability of the filter. The drawback with the use of the peat-sand filter is the addition of turbidity and color to the effluent. Color and turbidity can be expected to be added to the filter every time that the filter goes dry, which will occur regularly for most stormwater filters. The expected minimum effluent concentrations for the peat-sand filter would be 5 mg/L for suspended solids, 85 HACH color units, and 10 to 25 NTU for turbidity.

Activated carbon-sand

The carbon-sand filter provides good to excellent control for many pollutants, especially if the stormwater is not presettled. The carbon-sand filter does not have as good a removal efficiency when the effluent has been allowed to settle for several days. The influent pH and ionic strength will affect the effluent quality and removal efficiency for this filter. The interaction of these two parameters controls the effluent COD and toxicity, and the influent ionic strength controls the turbidity and the color. The influent pH appears to have the greatest effect on metals removal, with the greater removal efficiency and best effluent quality occurring when the pH is above neutral. The addition of salt to the influent positively influences the effluent turbidity but provides a negative influence on the effluent toxicity, color, and chemical oxygen demand.

The carbon-sand filter is also capable of removing pollutants immediately upon use through either sorption or ion-exchange. The carbon tested in these experiments uses sulfate as its exchangeable ion. A new carbon filter, however, will wash the carbon black dust out of the filter during the first couple of washings, and there may be a slight increase in turbidity for the first two or three storms if the runoff is presettled prior to filtration. The expected minimum effluent concentrations are 5 mg/L for suspended solids, 25 HACH color units, and 5 NTU for turbidity.

Zeolite-sand

The zeolite-sand filter provided moderate-to-good removal for several pollutants when the runoff was not allowed to settle prior to filtration. However, removal efficiency was not as good and occurred for fewer parameters when the runoff was presettled. Because the zeolite particles were very large (2 to 5 mm in diameter), the possibility exists that channels were formed in the media, and the runoff flowing through the channels did not have sufficient contact time with the media. The influent pH and ionic strength controlled the effluent toxicity, turbidity, chemical oxygen demand, and zinc. When the influent salt concentrations were high, the effluent turbidity and color were lower (compared to the effluent from the low salt influent conditions), but more hardness was added to the effluent.

The zeolite-sand mixture was expected to provide better removal than was shown in these experiments. However, if channels were present in the media and the underlying sand layer did not provide sufficient retention of water in the mixed zeolite-sand layer, then adequate contact time may not have been available for pollutant removal. The other problem with this zeolite is that it was designed for ammonia removal, and the pore size may not have been large enough to encourage removal of a wider variety of pollutants. The expected minimum effluent concentrations are 10 mg/L suspended solids, 75 HACH color units, and 15 NTU for turbidity.

Compost-sand

The compost-sand filter provided moderate-to-excellent removal of many pollutants when the runoff was not presettled. However, when the runoff was presettled, the compost-sand did little to improve water quality and worsened the color, hardness, and chemical oxygen demand of the effluent. Like the other sorption and ion-exchange media, heavy metals' removal was good in this media even for presettled runoff. The influent pH and ionic strength interacted to control the effluent quality and removal efficiency for hardness, chemical oxygen demand, zinc, and copper. For the metals, the poorest effluent quality occurred when the pH was low and the salt concentration was high. The addition of salt to the influent caused more hardness to be present in the effluent than when the runoff's salt concentration was not adjusted.

The compost-sand mixture has the ability to remove pollutants immediately upon use. However, like the peat-sand filter, when the filter goes dry between storms, color-producing organics are likely released from the medium and retained in the pores, waiting to be washed out during the next filtration. Also, the potential exists to wash solids from the media that are small enough to avoid being trapped during passage through the underlying sand filter. The minimum expected effluent concentrations for the compost-sand filter are 10 mg/L for suspended solids, 100 HACH color units, and 10 NTU for turbidity.

Enretech-sand

The Enretech-sand filter provided moderate control for several pollutants in untreated runoff, but it had little pollutant removal ability when the runoff was allowed to settle for several days. Low influent pH caused an increase in the effluent hardness while a high influent ionic strength caused the poorest effluent chemical oxygen demand. The interaction of pH and ionic strength controlled the removal of the heavy metals. The minimum expected effluent concentrations for the Enretech-sand filter are 10 mg/L for suspended solids, 80 HACH color units, and 10 NTU for turbidity.

Agrofiber-sand and Filter fabrics

The agrofiber-sand filter provided little removal with the exception of the heavy metals. The filter fabrics were capable of removing suspended solids from the runoff and pollutants associated with those solids. Of the filter fabrics tested, the Gunderboom provided the best overall removal capability. It would be an excellent choice for use as the top layer for gross solids removal.

Design of Filters for Specified Filtration Durations

The filtration durations measured during these tests can be used to develop preliminary filter designs. It is recommended that allowable suspended solids loadings be used as the primary controlling factor in this design. For these designs, clogging is defined to occur when the water flow rate through the medium becomes less than one meter per day. Filtration, obviously, will still occur when the flow rate becomes less than one meter per day; however, except for small rains in arid areas, much of the runoff would have to bypass the filter and would not be treated. Tables 77 and 78 summarize the observed filtration capacities of the different media (detailed plots of suspended solids loading versus flow rate are given in Appendix A).

The wide ranges in filter run times as a function of water loading are dependent mostly on the suspended solids content of the water, especially for the tests where the water was presettled. For this reason, the suspended solids loading capacities (Table 77) are recommended for use when selecting a filter.

Table 77. Filtration capacity as a function of suspended solids loading

Filtration media	Capacity to 20 m/ day (gSS/m^2)	Capacity to 10 m/ day (gSS/m^2)	Capacity to <1 m/ day (gSS/m^2)
Sand	150-400	400->2000	1200-4000
Peat-sand	100-300	150-1000	200-1700
Carbon-sand	150-900	200-1100	500->2000
Zeolite-sand	200-700	800-1500	1200->2000
Compost-sand	100-700	200-750	350-800
Enretech-sand	75-300	125-350	400-1500

Table 78. Filtration capacity of presettled water (<10 mg TSS/L influent)

Filtration media	Capacity to 20 m/day (m)	Capacity to 10 m/day (m)	Capacity to <1 m/day (m)
Sand	6-20	8->25	13->40
Peat-sand	3-17	4-22	7-30
Carbon-sand	5-25	6->25	15->40
Zeolite-sand	7-25	8->25	14->40
Compost-sand	3-20	4-30	6->30
Enretech-sand	3-11	4-25	15-30

The most restrictive materials (the Enretech and Forest Products media) are very fibrous and, even when mixed with sand, still show some compaction. The most granular media (activated carbon and zeolite) are relatively uniform in shape and size but are very large when compared to the sand grains. Sand was used with the carbon and the zeolite to reduce the water's flow rate through the media to increase contact time for better pollutant removal. The sand has the highest filtration rate because it has the most uniform shape and size.

The test observations indicate that only about 2.5 cm of the filter columns (about 10% of the column depth) was actually used for solids retention during these tests. It is assumed that a full-scale filter could use about 5 times these depths for solids retention if careful, selective piping to deeper depths, while preventing short-circuiting of the entire filter, was provided. The Metropolitan Washington (D.C.) Council of Governments recommends placing a turf grass layer on top of the media where the roots of the grass would cause channel development through the top layer only (Galli, 1990). They recommend that the roots of the grass cover do not extend below about one-half the filtration depth (up to approximately 12 cm).

Mechanical removal of the clogged layer to recover filter flow rates was not found to be very satisfactory during this research, but it has been used successfully during full-scale operations. Great care must be taken when removing this layer since loosening the media may enable trapped pollutants (associated with the suspended solids) to be easily flushed from the media.

The flow rates through filters that have been thoroughly dried between filter runs are significantly increased when compared to the flow rates prior to drying. The small-scale tests run here restricted complete drying during normal inter-event periods. Drying may occur more frequently in full-scale filters. Wetting and drying of filters (especially peat) has been known to produce solution channels through the media that significantly increases the flow. If these solution channels extend too far through the filter, however, the runoff may bypass part of the media and removal efficiency will be decreased. Table 79 shows the observed increases in filter flow rates for saturated (and partially clogged filters) and the associated flow capacity recovery for filters that have been thoroughly dried and then re-wetted. This data is approximate (not planned as part of the initial experimental design) and was collected from the presettled influent columns after the filters had been allowed to dry out for several weeks. After the columns had been allowed to dry, flow rates through the columns were determined using tap water.

The filter fabrics did not indicate any flow-rate improvements with wetting and drying. As expected, the peat-sand filter had the greatest improvement in flow capacity (by about ten times). The other media showed more modest improvements (but still about a two to three times increase in flow rate).

Table 79. Filter flow rates for saturated and partially clogged filters and recovered filtration capacity after thorough drying

Filter media	Saturated/partially clogged (m/day)	Recovered flow rate after drying (m/day)	Increase in flow (multiple)
Sand	13	40	3.1 X
Peat-sand	4	42	11 X
Carbon-sand	17	33	1.9 X
Zeolite-sand	17	39	2.3 X
Compost-sand	13	32	2.5 X
Enretech-sand	8.4	24	2.9 X
Forest-sand	8.4	17	2.0 X
EMCON fabric	850	850	1.0 X
Gunderboom fabric	200	200	1.0 X

The filter capacity ranges given in Table 77 were determined from several test conditions (both bench-scale and long-term performance testing). When designing a filter based on suspended solids removal and required flow rate, the media may be grouped into the approximate categories shown in Table 80. A multiplier of five (from the data shown in Table 77) was used to account for the greater anticipated filter flow capacity associated with full-scale operations. The values given in Table 80 are total suspended solids loadings on the filter and do not distinguish between whether the runoff is presettled or not.

Table 80. Filter categories based on capacity

Capacity to <1 m/day (gSS/m^2)	Capacity to 10 m/day (gSS/m^2)	Filtration media in category
5,000	1,250	Enretech-sand; Forest-sand
5,000	2,500	Compost-sand; Peat-sand
10,000	5,000	Zeolite-sand; Carbon-sand
15,000	7,500	Sand

Example Filter Designs

Filters can be designed based on the predicted annual discharge of suspended solids to the filtration device and the desired filter replacement interval. As an example, volumetric runoff coefficients (R_v) (as shown on Table 81) can be used to approximate the fraction of the annual rainfall that would occur as runoff for various land uses and surface conditions.

Table 82 summarizes likely suspended solids concentrations associated with different urban areas and waters.

Table 81. Volumetric runoff coefficients by land use (Pitt 1996)

Area	Volumetric Runoff Coefficient (R_v)
Low density residential land use	0.15
Medium density residential land use	0.3
High density residential land use	0.5
Commercial land use	0.8
Industrial land use	0.6
Paved areas	0.85
Sandy soils	0.1
Clayey soils	0.3

Table 82. Suspended solids concentration by land use (Pitt 1996)

Source Area	Suspended Solids Concentration (mg/L)
Roof runoff	10
Paved parking, storage, driveway, streets, and walk areas	50
Unpaved parking and storage areas	250
Landscaped areas	500
Construction site runoff	10,000
Combined sewer overflows	100
Detention pond water	20
Mixed stormwater	150
Effluent after high level of pretreatment of stormwater	5

Using the information in Tables 81 and 82 and the local annual rain depth, it is possible to estimate the annual suspended solids loading from an area and to size a needed stormwater filter. The following three examples illustrate these simple calculations (Pitt 1996).

Example 1

A 1.0 ha paved parking lot ($R_v = 0.85$), in an area receiving 1.0 m of rain per year:

$$(50 \text{ mg SS/L})\ (0.85)\ (1 \text{ m/yr})\ (1 \text{ ha})\ (10{,}000 \text{ m}^2\text{/ha})\ (1{,}000 \text{ L/m}^3)\ (\text{g}/1{,}000 \text{ mg})$$
$$= 425{,}000 \text{ g SS/yr}$$

Therefore, if a peat/sand filter is to be used having an expected suspended solids capacity of 5,000 g/m^2 before clogging, then 85 m^2 of this filter will be needed for each year of desired operation for this 1.0 ha site. This is about 0.9% of the paved area per year of operation. If this water is pretreated so the effluent has about 5 mg/L suspended solids, then only about 0.2% of the contributing paved area would be needed for the filter. A sand filter would only be about 1/3 of this size but would provide little added benefit if the runoff were pretreated.

Example 2

A 100 ha medium density residential area ($R_v = 0.3$), 1.0 m of rain per year:

$$(150 \text{ mg SS/L})\ (0.3)\ (1 \text{ m/yr})\ (100\text{ha})\ (10{,}000 \text{ m}^2\text{/ha})\ (1{,}000 \text{ L/m}^3)\ (\text{g}/1{,}000 \text{ mg})$$
$$= 45{,}000{,}000 \text{ g SS/yr}$$

The unit area loading of suspended solids for this residential area (425 kg SS/ha-yr) is about the same as in the previous example (450 kg SS/ha-yr), requiring about the same area dedicated for the filter. The reduced amount of runoff is balanced by the higher suspended solids concentration.

Example 3

A 1.0 ha rooftop in an area ($R_v = 0.85$) having 1.0 m of rain per year:

$$(10 \text{ mg SS/L})\ (0.85)\ (1 \text{ m/yr})\ (1 \text{ ha})\ (10{,}000 \text{ m}^2\text{/ha})\ (1{,}000 \text{ L/m}^3)\ (\text{g}/1{,}000 \text{ mg})$$
$$= 85{,}000 \text{ g SS/yr}$$

The unit area loading of suspended solids from this area is 85 kg SS/ha-yr and would only require a filter about 0.2% of the roofed drainage area per year of operation.

It is recommended that the filter media be about 50 cm in depth and that a surface grass cover be used (roots should not extend below the top half of the filter). This should enable a filtration life of about five times the basic life observed during these tests. In addition, it is highly recommended that significant pretreatment of the water be used to reduce the suspended solids concentrations to about 10 mg/L before filtration for pollutant removal. This pretreatment can be accomplished using grass filters, wet detention ponds, or other specialized treatment (such as the sedimentation chamber in the multi-chambered treatment train described by Pitt, 1996). The selection of the specific filtration media should be based on the desired pollutant reductions, and the selection should include amendments to plain sand if immediate and permanent pollutant reductions are desired.

A more detailed design procedure for a sand filter for stormwater treatment is given by Urbonas (1999). Similar to the approach shown above, it is based on hydraulic capacity of the filter media. It also specifically addresses the maintenance needs of the filter media by inserting a maintenance frequency variable into the TSS removal calculation. Future work by the UAB group also will be addressing maintenance issues. This difference between the UAB group and Urbonas' work will be investigating the impact that the non-sand media have on required maintenance cycles and life of the filter before media replacement will be needed. In order to compare our results to the results of Urbonas and others, sand will be used as a control filter.

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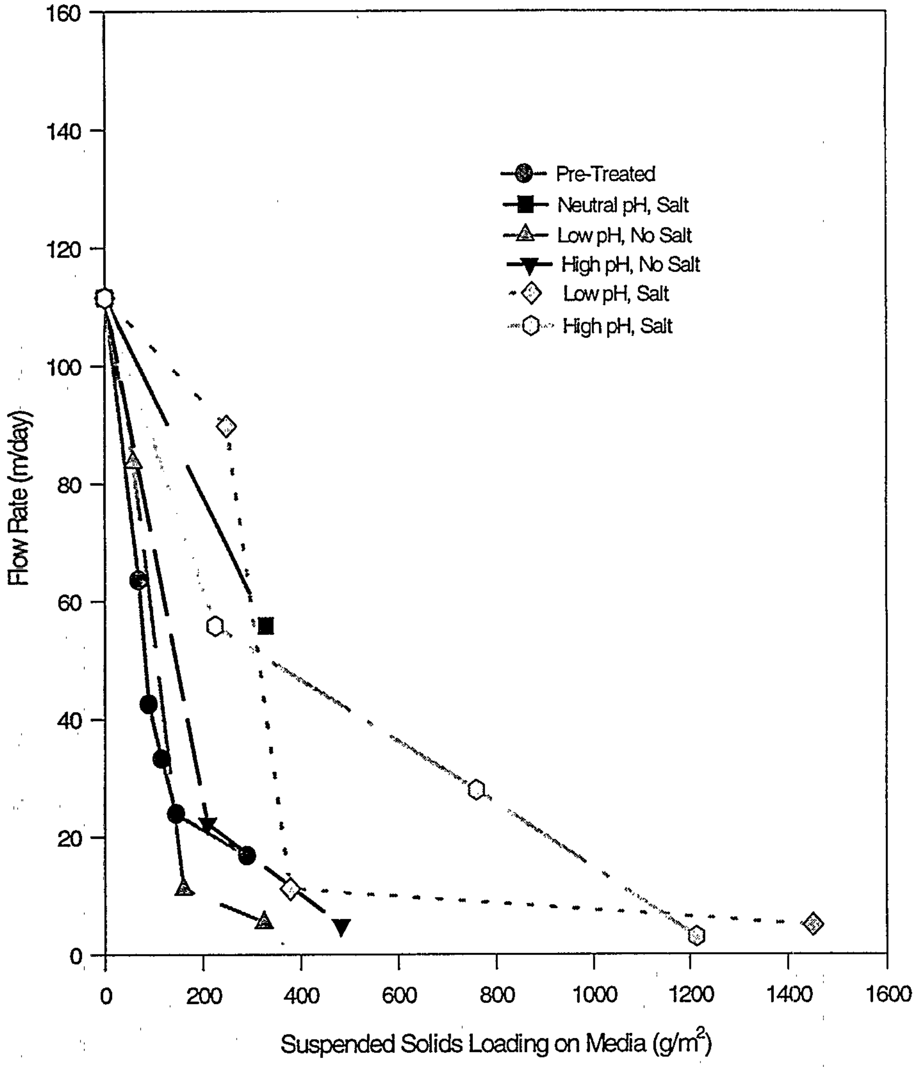
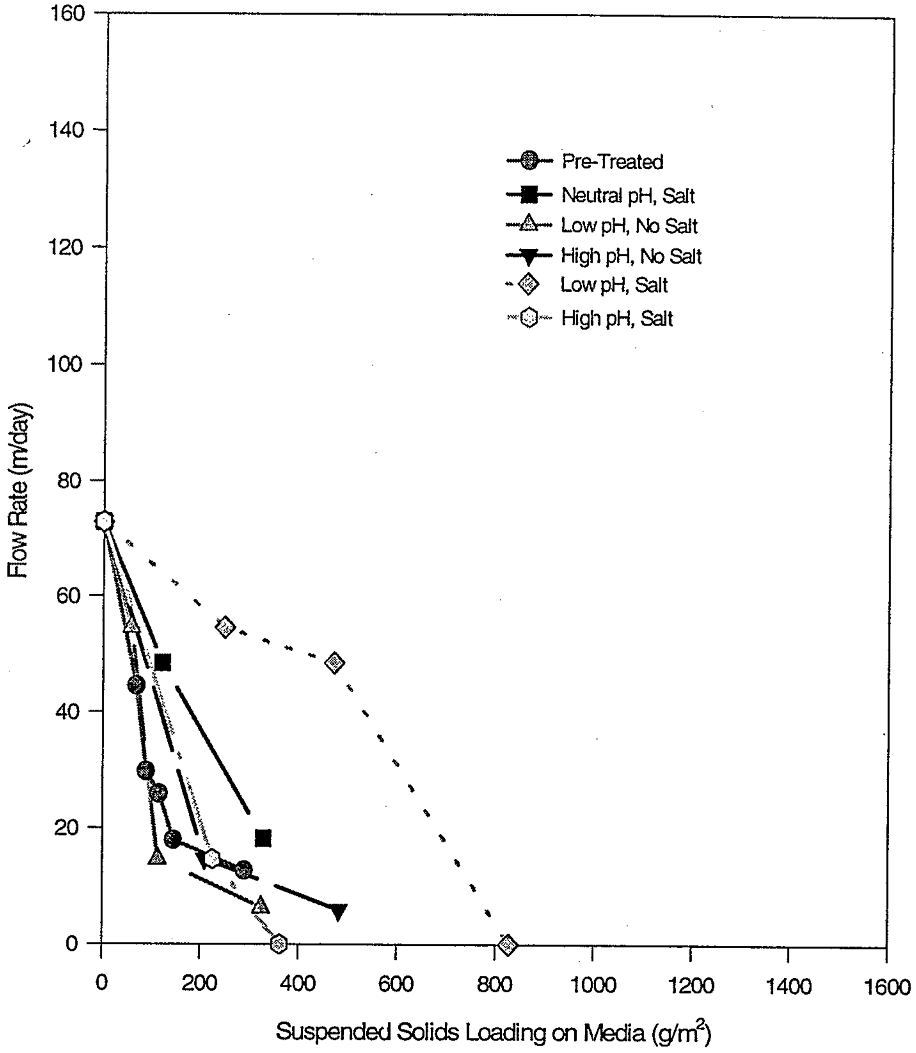
Appendix A:
Loadings on Media

Carbon-Sand

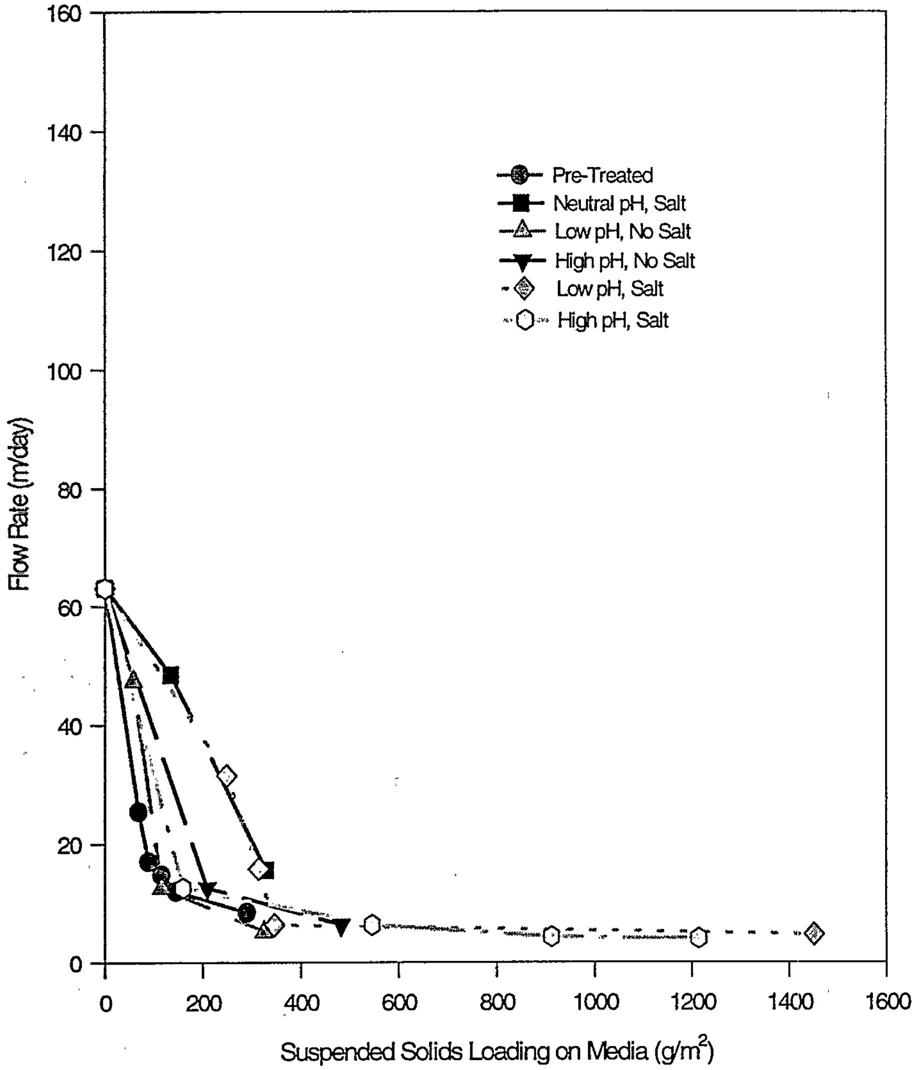


Pre-Treated
Neutral pH, Salt
Low pH, No Salt
High pH, No Salt
Low pH, Salt
High pH, Salt
Flow Rate (m/day)
0
20
40
60
80
100
120
140
160
0
200
400
600
800
1000
1200
1400
1600
Suspended Solids Loading on Media (g/m^2)

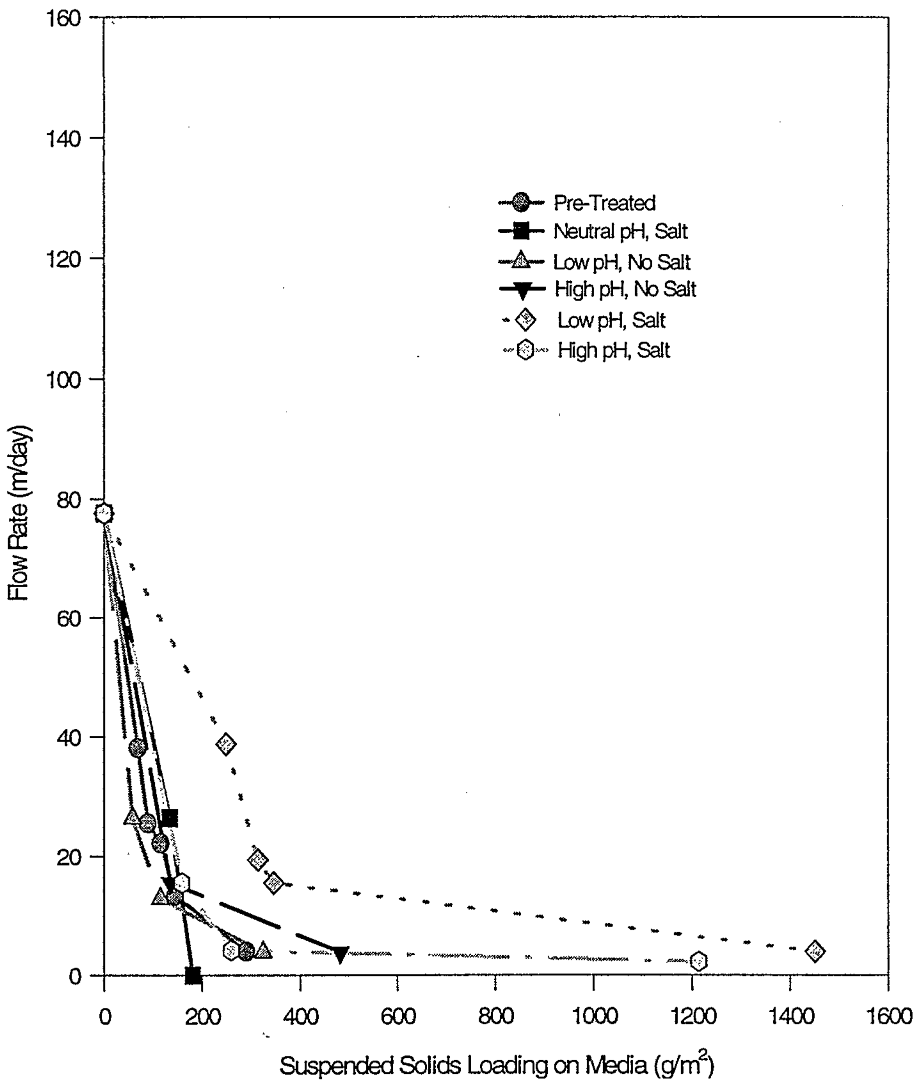
Compost-Sand



Enretech-Sand

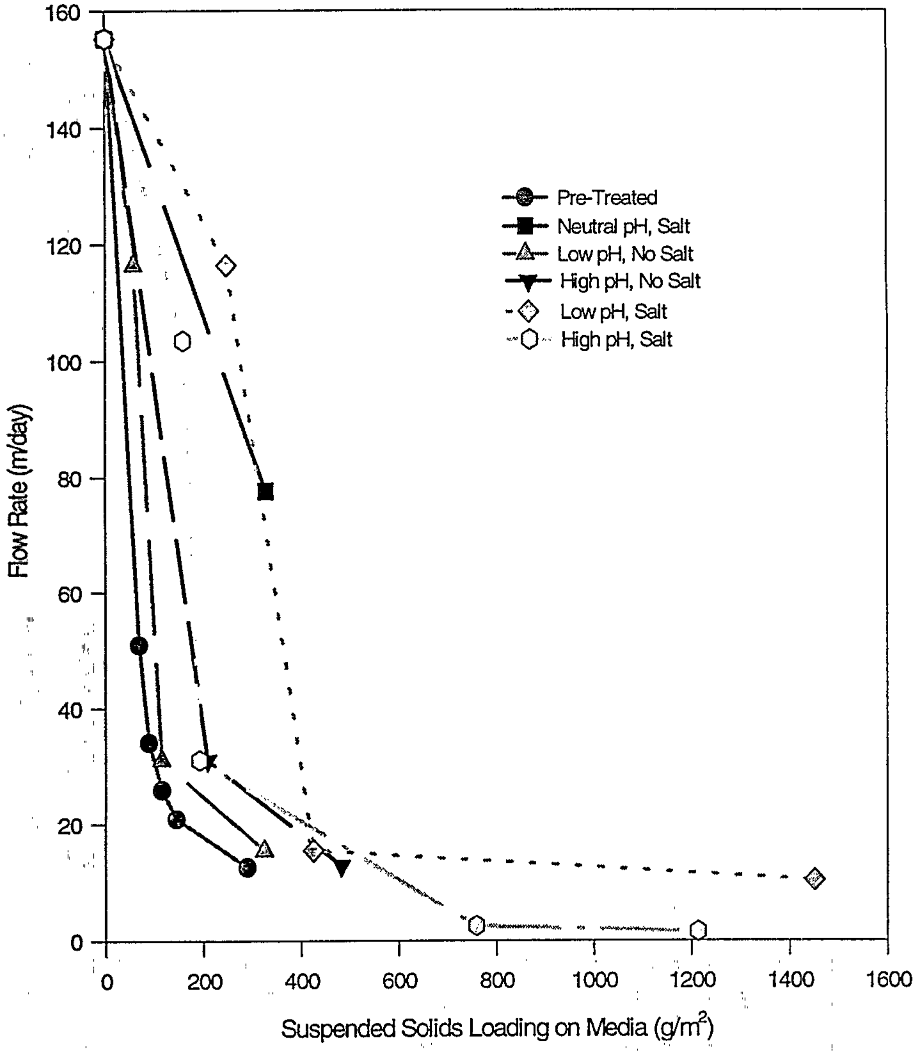


Peat-Sand

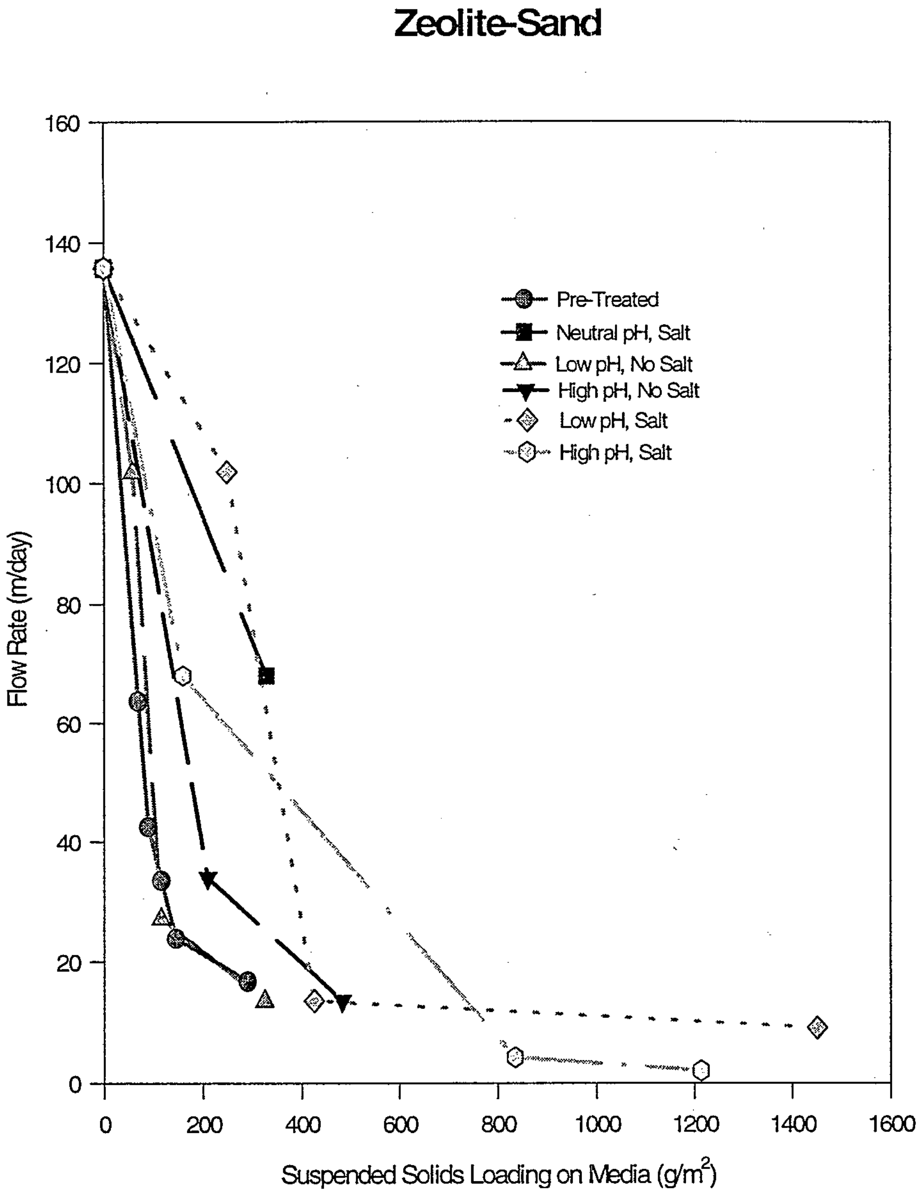


Pre-Treated
Neutral pH, Salt
Low pH, No Salt
High pH, No Salt
Low pH, Salt
High pH, Salt
Flow Rate (m/day)
160
140
120
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
Suspended Solids Loading on Media (g/m^2)

Sand



160
140
120
100
80
60
40
20
0
Flow Rate (m/day)
0
200
400
600
800
1000
1200
1400
1600
Suspended Solids Loading on Media (g/m²)
Pre-Treated
Neutral pH, Salt
Low pH, No Salt
High pH, No Salt
Low pH, Salt
High pH, Salt


Zeolite-Sand
Flow Rate (m/day)
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
1400
1600
Suspended Solids Loading on Media (g/m^2)
Pre-Treated
Neutral pH, Salt
Low pH, No Salt
High pH, No Salt
Low pH, Salt
High pH, Salt

Appendix B:
Bench-Scale Test Results

Toxicity
Turbidity
Conductivity
Color
pH
Chemical Oxygen Demand
Hardness
Suspended Solids
Particle Size Distribution (6 to 8 µm)
Particle Size Distribution (20 to 22 µm)
Particle Size Distribution (52 to 54 µm)
Particle Size Distribution (4 to 128 µm)
Zinc
Copper

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

TOXICITY (I 25 % Reduction)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	0	0	N/A	27	7	74	99	0	100
Grab #2	0	0	N/A	18	0	100	98	0	100
Grab #3	11	0	100	72	0	100	94	0	100
Grab #4	10	2	80	3	0	100	76	0	100
Grab #5	2	10	-400	0	0	N/A	74	0	100
Grab #6	8	7	13	2	0	100	45	33	27
Peat-Sand									
Grab #1	0	23	N/A	27	19	30	99	1	99
Grab #2	0	4	N/A	18	0	100	98	0	100
Grab #3	11	0	100	72	0	100	94	5	95
Grab #4	10	1	90	3	0	100	76	3	96
Grab #5	2	no sample	N/A	0	0	N/A	74	3	96
Grab #6	8	no sample	N/A	2	0	100	45	2	96
Zeolite-Sand									
Grab #1	0	10	N/A	27	21	22	99	78	21
Grab #2	0	0	N/A	18	0	100	98	94	4
Grab #3	11	0	100	72	0	100	94	86	9
Grab #4	10	0	100	3	5	-67	76	86	-13
Grab #5	2	5	-150	0	7	N/A	74	49	34
Grab #6	8	0	100	2	0	100	45	54	-20

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

TOXICITY (I 25 % Reduction) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	0	0	N/A	27	19	30	99	11	89
Grab #2	0	0	N/A	18	0	100	98	3	97
Grab #3	11	0	100	72	0	100	94	12	87
Grab #4	10	0	100	3	0	100	76	0	100
Grab #5	2	0	100	0	0	N/A	74	0	100
Grab #6	8	0	100	2	0	100	45	1	98
Enretech-Sand									
Grab #1	0	12	N/A	27	31	-15	99	93	6
Grab #2	0	11	N/A	18	0	100	98	96	2
Grab #3	11	10	9	72	0	100	94	87	7
Grab #4	10	4	60	3	18	-500	76	92	-21
Grab #5	2	3	-50	0	0	N/A	74	51	31
Grab #6	8	1	88	2	5	-150	45	58	-29
Sand									
Grab #1	0	0	N/A	27	0	100	99	98	1
Grab #2	0	10	N/A	18	0	100	98	90	8
Grab #3	11	6	45	72	0	100	94	87	7
Grab #4	10	8	20	3	0	100	76	84	-11
Grab #5	2	0	100	0	6	N/A	74	79	-7
Grab #6	8	3	63	2	0	100	45	59	-31

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

TOXICITY (I 25 % Reduction) (Continued) Summer 1995

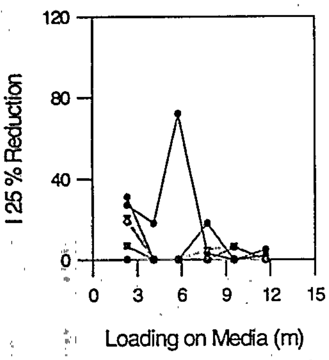
SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	26	2	92	100	64	36
Grab #2	22	22	0	100	93	7
Grab #3	23	4	N/A	100	100	0
Grab #4	11	13	-18	100	100	0
Grab #5	51	0	100	100	100	0
Grab #6	16	0	100	87	86	1
Peat-Sand						
Grab #1	26	100	-285	100	82	18
Grab #2	22	64	-191	100	17	83
Grab #3	23	77	N/A	100	31	69
Grab #4	11	72	-555	100	30	70
Grab #5	51	31	39	100	72	28
Grab #6	16	29	-81	87	20	77
Zeolite-Sand						
Grab #1	26	0	100	100	100	0
Grab #2	22	0	100	100	100	0
Grab #3	23	0	N/A	100	100	0
Grab #4	11	0	100	100	100	0
Grab #5	51	0	100	100	100	0
Grab #6	16	0	100	87	79	9

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

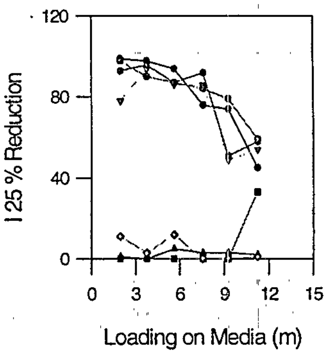
TOXICITY (I 25 % Reduction) (continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		2.582 m			2.582 m	
Grab #2		4.547 m			4.547 m	
Grab #3		6.512 m			6.512 m	
Grab #4		8.757 m			9.262 m	
Grab #5		10.890 m			11.676 m	
Grab #6		13.192 m			13.978 m	
Compost-Sand						
Grab #1	26	1	96	100	4	96
Grab #2	22	0	100	100	7	93
Grab #3	23	0	N/A	100	13	87
Grab #4	11	0	100	100	no sample	N/A
Grab #5	51	5	90	100	no sample	N/A
Grab #6	16	no sample	N/A	87	no sample	N/A
Enretech-Sand						
Grab #1	26	26	0	100	100	0
Grab #2	22	0	100	100	100	0
Grab #3	23	25	N/A	100	100	0
Grab #4	11	19	-73	100	100	0
Grab #5	51	12	76	100	100	0
Grab #6	16	23	-44	87	83	5
Sand						
Grab #1	26	9	65	100	100	0
Grab #2	22	15	32	100	100	0
Grab #3	23	22	N/A	100	100	0
Grab #4	11	1	91	100	100	0
Grab #5	51	13	75	100	100	0
Grab #6	16	22	-38	87	87	0

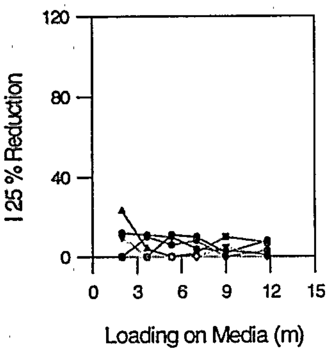
Low pH, Low Salt



High pH, Low Salt

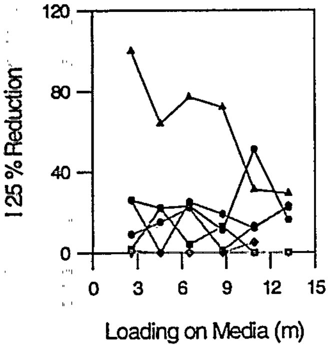


Neutral pH, High Salt

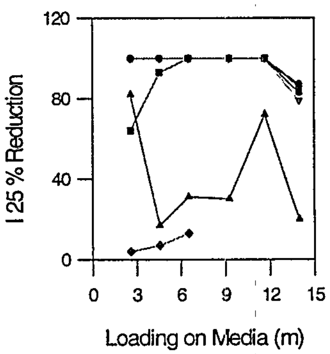


- ● Blank
- ■ Carbon-Sand
- ▲ Peat-Sand
- ▼ Zeolite-Sand
- ◇ Compost-Sand
- ● Enretech-Sand
- ● Sand

Low pH, High Salt



High pH, High Salt



TOXICITY: Bench-Scale Testing

CONTRAST TABLE EFFLUENT QUALITY TOXICITY

CARBON-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	1	6	1
2	1	-1	-1	6	6	6
3	-1	1	-1	7	6	4
4	1	1	1	91	6	6
Effect	44	45	40	26		4

PEAT-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	3	6	3
2	1	-1	-1	2	6	1
3	-1	1	-1	62	6	11
4	1	1	1	42	6	11
Effect	-11	49	-10	27		8

ZEOLITE-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	6	6	3
2	1	-1	-1	75	6	8
3	-1	1	-1	0	6	0
4	1	1	1	97	6	4
Effect	83	8	14	44		4

COMPOST-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	3	6	3
2	1	-1	-1	5	6	2
3	-1	1	-1	1	5	1
4	1	1	1	8	3	3
Effect	4	1	3	4		3

ENRETECH-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	9	6	5
2	1	-1	-1	80	6	8
3	-1	1	-1	18	6	4
4	1	1	1	97	6	3
Effect	75	13	5	51		5

SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	0	6	0
2	1	-1	-1	83	6	5
3	-1	1	-1	14	6	3
4	1	1	1	98	6	2
Effect	84	14	1	49		3

CONTRAST TABLE REMOVAL EFFICIENCY TOXICITY

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	95	5	5.20
2	1	-1	-1	88	6	12.17
3	-1	1	-1	60	6	21.94
4	1	1	1	7	6	5.84
Effect	-30	-58	-23	62		14

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	86	5	14.00
2	1	-1	-1	97	6	0.82
3	-1	1	-1	-218	6	82.44
4	1	1	1	58	6	11.18
Effect	143	-172	132	6		44

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	51	5	33.14
2	1	-1	-1	6	6	8.28
3	-1	1	-1	100	5	0.00
4	1	1	1	2	6	1.50
Effect	-72	22	-27	40		16

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	86	5	14.00
2	1	-1	-1	95	6	2.33
3	-1	1	-1	97	5	1.96
4	1	1	1	92	3	2.65
Effect	2	4	-7	93		8

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-93	5	111.69
2	1	-1	-1	-1	6	8.81
3	-1	1	-1	8	6	27.51
4	1	1	1	1	6	0.83
Effect	42	51	-50	-21		50

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	100	5	0.00
2	1	-1	-1	-6	6	5.95
3	-1	1	-1	38	6	19.90
4	1	1	1	0	6	0.00
Effect	-72	-28	34	33		11

TURBIDITY (NTU)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	7.0	2.7	61	6.6	1.2	82	11	1.9	82
Grab #2	5.5	2.4	56	8.9	1.0	89	10	1.8	82
Grab #3	7.0	2.4	66	11	1.7	85	11	5.0	55
Grab #4	7.0	2.0	71	9.3	2.5	73	13	10	21
Grab #5	7.2	1.8	75	6.8	2.2	68	13	2.6	80
Grab #6	6.0	1.5	75	7.1	3.7	48	10	2.5	75
Peat-Sand									
Grab #1	7.0	5.0	29	6.6	21	-218	11	62	-490
Grab #2	5.5	3.2	42	8.9	16	-80	10	32	-220
Grab #3	7.0	3.4	51	11	19	-73	11	26	-136
Grab #4	7.0	25	-257	9.3	28	-201	13	45	-246
Grab #5	7.2	no sample	N/A	6.8	6.4	6	13	36	-177
Grab #6	6.0	no sample	N/A	7.1	11	-55	10	32	-220
Zeolite-Sand									
Grab #1	7.0	3.4	51	6.6	9.9	-50	11	17	-62
Grab #2	5.5	1.6	71	8.9	5.7	36	10	7.1	29
Grab #3	7.0	3.4	51	11	7.2	35	11	4.4	60
Grab #4	7.0	4.7	33	9.3	7.9	15	13	13	0
Grab #5	7.2	2.1	71	6.8	3.8	44	13	5.3	59
Grab #6	6.0	1.7	72	7.1	5.5	23	10	3.5	65

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

TURBIDITY (NTU) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	7.0	4.2	40	6.6	8.4	-27	11	18	-71
Grab #2	5.5	1.8	67	8.9	20.0	-125	10	12	-20
Grab #3	7.0	2.4	66	11.0	8.4	24	11	31	-182
Grab #4	7.0	2.1	70	9.3	9.7	-4	13	23	-77
Grab #5	7.2	1.7	76	6.8	6.9	-1	13	10	23
Grab #6	6.0	1.9	68	7.1	15.0	-111	10	14	-40
Enretech-Sand									
Grab #1	7.0	4.8	31	6.6	12.0	-82	11	10	5
Grab #2	5.5	2.4	56	8.9	14.0	-57	10	4.5	55
Grab #3	7.0	3.7	47	11.0	4.3	61	11	14	-27
Grab #4	7.0	3.3	53	9.3	14.0	-51	13	16	-23
Grab #5	7.2	3.2	56	6.8	9.8	-44	13	7.5	42
Grab #6	6.0	3.1	48	7.1	15.0	-111	10	4.0	60
Sand									
Grab #1	7.0	5.7	19	6.6	5.0	24	11	11	-5
Grab #2	5.5	3.4	38	8.9	12.0	-35	10	3.2	68
Grab #3	7.0	5.2	26	11.0	10.0	9	11	3.0	73
Grab #4	7.0	5.1	27	9.3	25.0	-169	13	15	-15
Grab #5	7.2	3.2	56	6.8	7.8	-15	13	5.7	56
Grab #6	6.0	2.3	62	7.1	9.2	-30	10	3.5	65

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

TURBIDITY (NTU) (Continued)

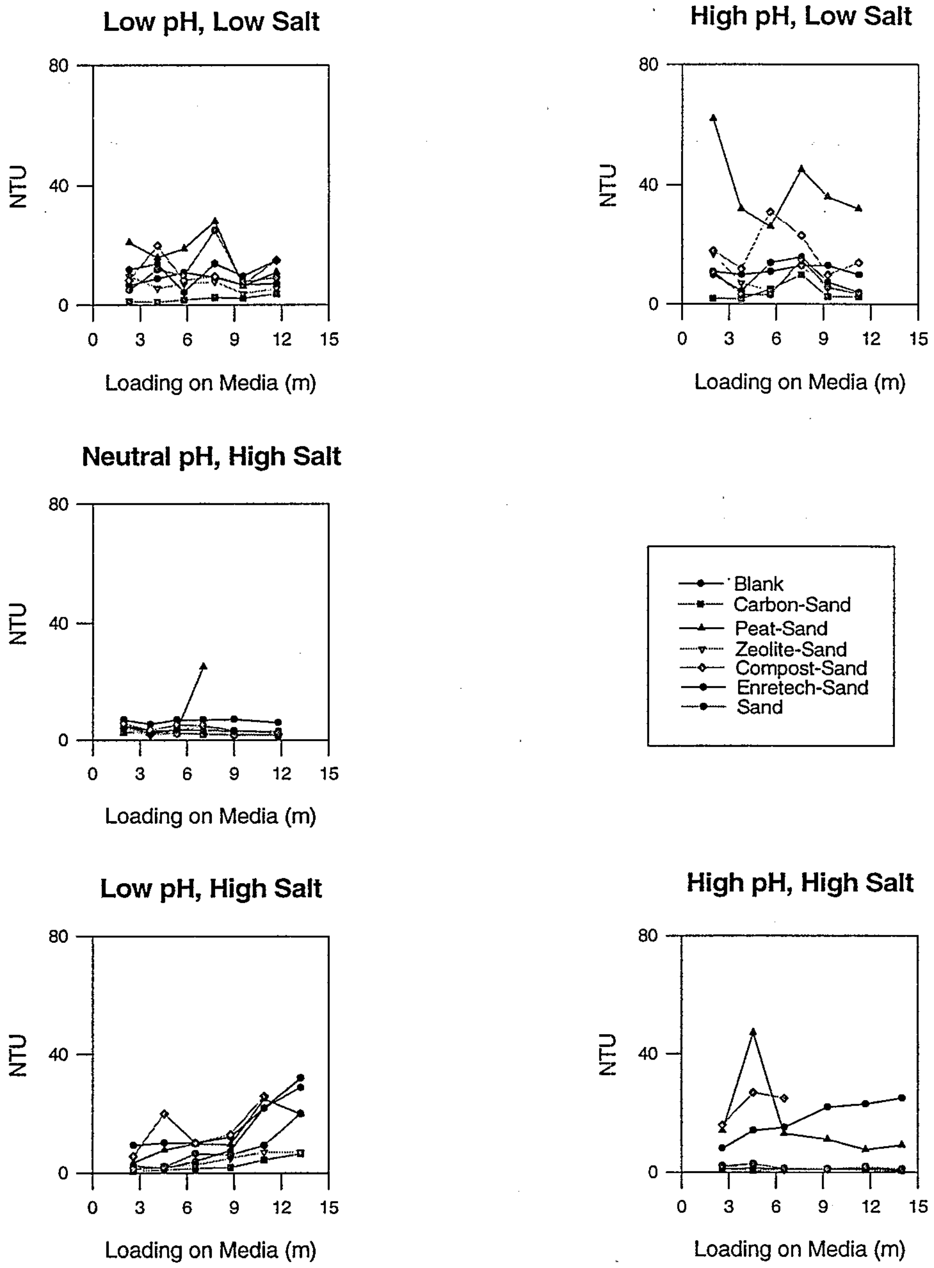
Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	9.2	0.6	93	8.0	1.1	86
Grab #2	10	1.0	90	14	0.6	96
Grab #3	10	1.6	84	15	0.8	94
Grab #4	12	1.9	84	22	0.9	96
Grab #5	22	4.4	80	23	0.7	97
Grab #6	32	6.5	80	25	0.5	98
Peat-Sand						
Grab #1	9.2	3.4	63	8.0	14	-75
Grab #2	10	7.7	23	14	47	-236
Grab #3	10	9.7	3	15	13	13
Grab #4	12	9.5	21	22	11	50
Grab #5	22	25	-14	23	7.5	67
Grab #6	32	20	38	25	9.0	64
Zeolite-Sand						
Grab #1	9.2	1.6	83	8.0	2.0	75
Grab #2	10	2.3	77	14	1.8	87
Grab #3	10	2.7	73	15	0.8	94
Grab #4	12	5.0	58	22	1.0	95
Grab #5	22	7.0	68	23	1.2	95
Grab #6	32	7.0	78	25	0.7	97

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

TURBIDITY (NTU) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	9.2	5.5	40	8.0	16	-100
Grab #2	10	20	-100	14	27	-93
Grab #3	10	10	0	15	25	-67
Grab #4	12	13	-8	22	no sample	N/A
Grab #5	22	26	-18	23	no sample	N/A
Grab #6	32	no sample	N/A	25	no sample	N/A
Enretech-Sand						
Grab #1	9.2	2.5	73	8.0	1.3	84
Grab #2	10	1.5	85	14	1.3	91
Grab #3	10	4.0	60	15	1.1	93
Grab #4	12	7.5	38	22	1.0	96
Grab #5	22	22.0	0	23	1.1	95
Grab #6	32	29.0	9	25	1.0	96
Sand						
Grab #1	9.2	1.2	87	8.0	2.1	74
Grab #2	10	2.0	80	14	2.8	80
Grab #3	10	6.5	35	15	1.2	92
Grab #4	12	6.0	50	22	1.1	95
Grab #5	22	9.2	58	23	1.8	92
Grab #6	32	20.0	38	25	1.0	96



TURBIDITY: Bench-Scale Testing

CONTRAST TABLE EFFLUENT QUALITY TURBIDITY

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	2.05	6	0.40
2	1	-1	-1	4.02	6	1.34
3	-1	1	-1	2.67	6	0.94
4	1	1	1	0.77	6	0.09
Effect	0.03	-1.32	-1.93	2.38		0.85

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	16.90	6	3.11
2	1	-1	-1	38.83	6	5.29
3	-1	1	-1	12.55	6	3.34
4	1	1	1	16.92	6	6.10
Effect	13	-13	-9	21.30		4.64

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	6.67	6	0.87
2	1	-1	-1	8.38	6	2.21
3	-1	1	-1	4.27	6	0.98
4	1	1	1	1.26	6	0.22
Effect	-1	-5	-2	5.14		1.29

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	11.40	6	2.07
2	1	-1	-1	18.00	6	3.21
3	-1	1	-1	14.90	5	3.64
4	1	1	1	22.67	3	3.38
Effect	7	4	1	16.74		3.11

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	11.52	6	1.63
2	1	-1	-1	9.33	6	2.02
3	-1	1	-1	11.08	6	4.72
4	1	1	1	1.12	6	0.06
Effect	-6	-4	-4	8.26		2.69

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	11.50	6	2.86
2	1	-1	-1	6.90	6	2.04
3	-1	1	-1	7.48	6	2.78
4	1	1	1	1.67	6	0.29
Effect	-5	-5	-1	6.89		2.25

CONTRAST TABLE REMOVAL EFFICIENCY TURBIDITY

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	74	6	6.12
2	1	-1	-1	66	6	9.89
3	-1	1	-1	85	6	2.17
4	1	1	1	95	6	1.78
Effect	0	20	9	80		6

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-104	6	35.80
2	1	-1	-1	-248	6	50.90
3	-1	1	-1	22	6	10.95
4	1	1	1	-20	6	48.41
Effect	-93	177	51	-87		40

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	17	6	14.07
2	1	-1	-1	25	6	20.16
3	-1	1	-1	73	6	3.61
4	1	1	1	2	6	1.50
Effect	-32	16	-40	29		12

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-41	6	25.39
2	1	-1	-1	-61	6	28.39
3	-1	1	-1	-17	5	22.92
4	1	1	1	-87	3	10.04
Effect	-45	-1	-24	-51		26

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-47	6	23.88
2	1	-1	-1	19	6	15.90
3	-1	1	-1	44	6	14.11
4	1	1	1	93	6	1.88
Effect	57	83	-9	27		16

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-36	5	28.16
2	1	-1	-1	40	6	16.13
3	-1	1	-1	58	6	8.79
4	1	1	1	88	6	3.67
Effect	53	71	-23	38		17

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

CONDUCTIVITY (µS/cm)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	8,000	8,100	-1	290	280	3	210	200	5
Grab #2	8,500	8,300	2	290	279	4	208	170	18
Grab #3	7,800	8,700	-12	295	300	-2	202	180	11
Grab #4	8,100	8,700	-7	315	300	5	200	180	10
Grab #5	8,500	7,800	8	318	340	-7	200	200	0
Grab #6	8,200	8,500	-4	292	200	32	200	200	0
Peat-Sand									
Grab #1	8,000	9,200	-15	290	308	-6	210	70	67
Grab #2	8,500	9,100	-7	290	280	3	208	73	65
Grab #3	7,800	9,050	-16	295	335	-14	202	98	51
Grab #4	8,100	9,050	-12	315	300	5	200	115	43
Grab #5	8,500	no sample	N/A	318	270	15	200	135	33
Grab #6	8,200	no sample	N/A	292	292	0	200	140	30
Zeolite-Sand									
Grab #1	8,000	9,050	-13	290	300	-3	210	185	12
Grab #2	8,500	9,100	-7	290	319	-10	208	180	13
Grab #3	7,800	9,900	-27	295	280	5	202	190	6
Grab #4	8,100	9,300	-15	315	285	10	200	197	2
Grab #5	8,500	9,700	-14	318	321	-1	200	197	2
Grab #6	8,200	9,850	-20	292	290	1	200	205	-3

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

CONDUCTIVITY (µS/cm) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	8,000	9,200	-15	290	350	-21	210	192	9
Grab #2	8,500	9,900	-16	290	370	-28	208	170	18
Grab #3	7,800	9,800	-26	295	359	-22	202	170	16
Grab #4	8,100	9,700	-20	315	391	-24	200	170	15
Grab #5	8,500	10,000	-18	318	317	0	200	215	-8
Grab #6	8,200	9,900	-21	292	310	-6	200	190	5
Enretech-Sand									
Grab #1	8,000	9,900	-24	290	310	-7	210	198	6
Grab #2	8,500	9,950	-17	290	321	-11	208	205	1
Grab #3	7,800	9,800	-26	295	290	2	202	205	-1
Grab #4	8,100	10,500	-30	315	330	-5	200	210	-5
Grab #5	8,500	9,800	-15	318	317	0	200	200	0
Grab #6	8,200	8,850	-8	292	290	1	200	205	-3
Sand									
Grab #1	8,000	9,700	-21	290	313	-8	210	200	5
Grab #2	8,500	9,400	-11	290	315	-9	208	200	4
Grab #3	7,800	9,100	-17	295	322	-9	202	200	1
Grab #4	8,100	8,600	-6	315	318	-1	200	205	-3
Grab #5	8,500	8,150	4	318	301	5	200	205	-3
Grab #6	8,200	8,500	-4	292	no sample	N/A	200	210	-5

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

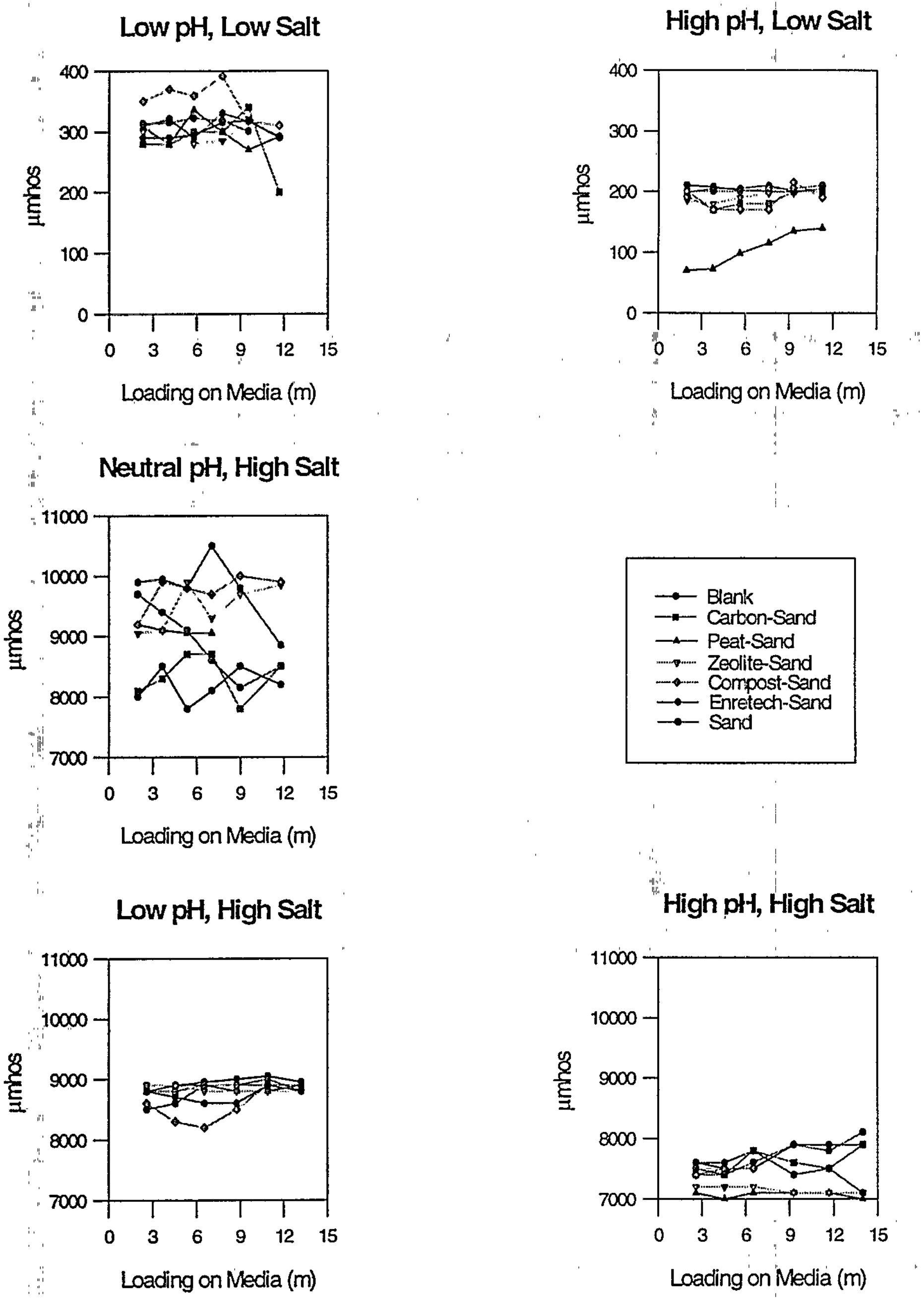
CONDUCTIVITY (µS/cm) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		2.582 m			2.582 m	
Grab #2		4.547 m			4.547 m	
Grab #3		6.512 m			6.512 m	
Grab #4		8.757 m			9.262 m	
Grab #5		10.890 m			11.676 m	
Grab #6		13.192 m			13.978 m	
Activated Carbon-Sand						
Grab #1	8,900	8,800	1	7,600	7,400	3
Grab #2	8,900	8,800	1	7,500	7,400	1
Grab #3	8,950	8,900	1	7,500	7,800	-4
Grab #4	9,000	8,900	1	7,900	7,600	4
Grab #5	9,050	8,900	2	7,900	7,500	5
Grab #6	8,950	8,900	1	7,900	7,900	0
Peat-Sand						
Grab #1	8,900	8,800	1	7,600	7,100	7
Grab #2	8,900	8,900	0	7,500	7,000	7
Grab #3	8,950	8,900	1	7,500	7,100	5
Grab #4	9,000	8,800	2	7,900	7,100	10
Grab #5	9,050	8,800	3	7,900	7,100	10
Grab #6	8,950	8,900	1	7,900	7,000	11
Zeolite-Sand						
Grab #1	8,900	8,900	0	7,600	7,200	5
Grab #2	8,900	8,900	0	7,500	7,200	4
Grab #3	8,950	8,800	2	7,500	7,200	4
Grab #4	9,000	8,800	2	7,900	7,100	10
Grab #5	9,050	8,800	3	7,900	7,100	10
Grab #6	8,950	8,800	2	7,900	7,100	10

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

CONDUCTIVITY (μS/cm) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	8,900	8,600	3	7,600	7,400	3
Grab #2	8,900	8,300	7	7,500	7,500	0
Grab #3	8,950	8,200	8	7,500	7,500	0
Grab #4	9,000	8,500	6	7,900	no sample	N/A
Grab #5	9,050	8,900	2	7,900	no sample	N/A
Grab #6	8,950	no sample	N/A	7,900	no sample	N/A
Enretech-Sand						
Grab #1	8,900	8,800	1	7,600	7,600	0
Grab #2	8,900	8,700	2	7,500	7,600	-1
Grab #3	8,950	8,600	4	7,500	7,800	-4
Grab #4	9,000	8,600	4	7,900	7,400	6
Grab #5	9,050	8,900	2	7,900	7,500	5
Grab #6	8,950	8,800	2	7,900	7,100	10
Sand						
Grab #1	8,900	8,500	4	7,600	7,500	1
Grab #2	8,900	8,600	3	7,500	7,400	1
Grab #3	8,950	8,900	1	7,500	7,600	-1
Grab #4	9,000	8,900	1	7,900	7,900	0
Grab #5	9,050	9,000	1	7,900	7,800	1
Grab #6	8,950	8,800	2	7,900	8,100	-3



CONDUCTIVITY: Bench-Scale Testing

COLOR (HACH Units)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	70	30	57	67	20	70	100	22	78
Grab #2	85	40	53	65	14	78	100	20	80
Grab #3	87	45	48	85	19	78	100	23	77
Grab #4	80	30	63	80	23	71	100	33	67
Grab #5	80	25	69	82	35	57	100	33	67
Grab #6	53	30	43	71	38	46	100	30	70
Peat-Sand									
Grab #1	70	75	-7	67	93	-39	100	100	0
Grab #2	85	85	0	65	89	-37	100	100	0
Grab #3	87	75	14	85	95	-12	100	100	0
Grab #4	80	100	-25	80	100	-25	100	100	0
Grab #5	80	no sample	N/A	82	75	9	100	100	0
Grab #6	53	no sample	N/A	71	75	-6	100	100	0
Zeolite-Sand									
Grab #1	70	68	3	67	68	-1	100	100	0
Grab #2	85	70	18	65	73	-12	100	76	24
Grab #3	87	84	3	85	72	15	100	50	50
Grab #4	80	65	19	80	72	10	100	70	30
Grab #5	80	74	8	82	73	11	100	55	45
Grab #6	53	68	-28	71	55	23	100	50	50

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

COLOR (HACH Units) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	70	100	-43	67	100	-49	100	100	0
Grab #2	85	100	-18	65	100	-54	100	100	0
Grab #3	87	100	-15	85	100	-18	100	100	0
Grab #4	80	100	-25	80	100	-25	100	100	0
Grab #5	80	100	-25	82	97	-18	100	100	0
Grab #6	53	100	-89	71	100	-41	100	100	0
Enretech-Sand									
Grab #1	70	85	-21	67	49	27	100	70	30
Grab #2	85	73	14	65	80	-23	100	65	35
Grab #3	87	82	6	85	50	41	100	70	30
Grab #4	80	82	-3	80	81	-1	100	70	30
Grab #5	80	83	-4	82	79	4	100	62	38
Grab #6	53	75	-42	71	75	-6	100	57	43
Sand									
Grab #1	70	74	-6	67	54	19	100	65	35
Grab #2	85	85	0	65	55	15	100	40	60
Grab #3	87	78	10	85	81	5	100	35	65
Grab #4	80	85	-6	80	89	-11	100	80	20
Grab #5	80	77	4	82	70	15	100	70	30
Grab #6	53	84	-58	71	70	1	100	65	35

FILTRATION MEDIA EVALUATION: Bench-Scale Te

COLOR (HACH Units) (Continued)

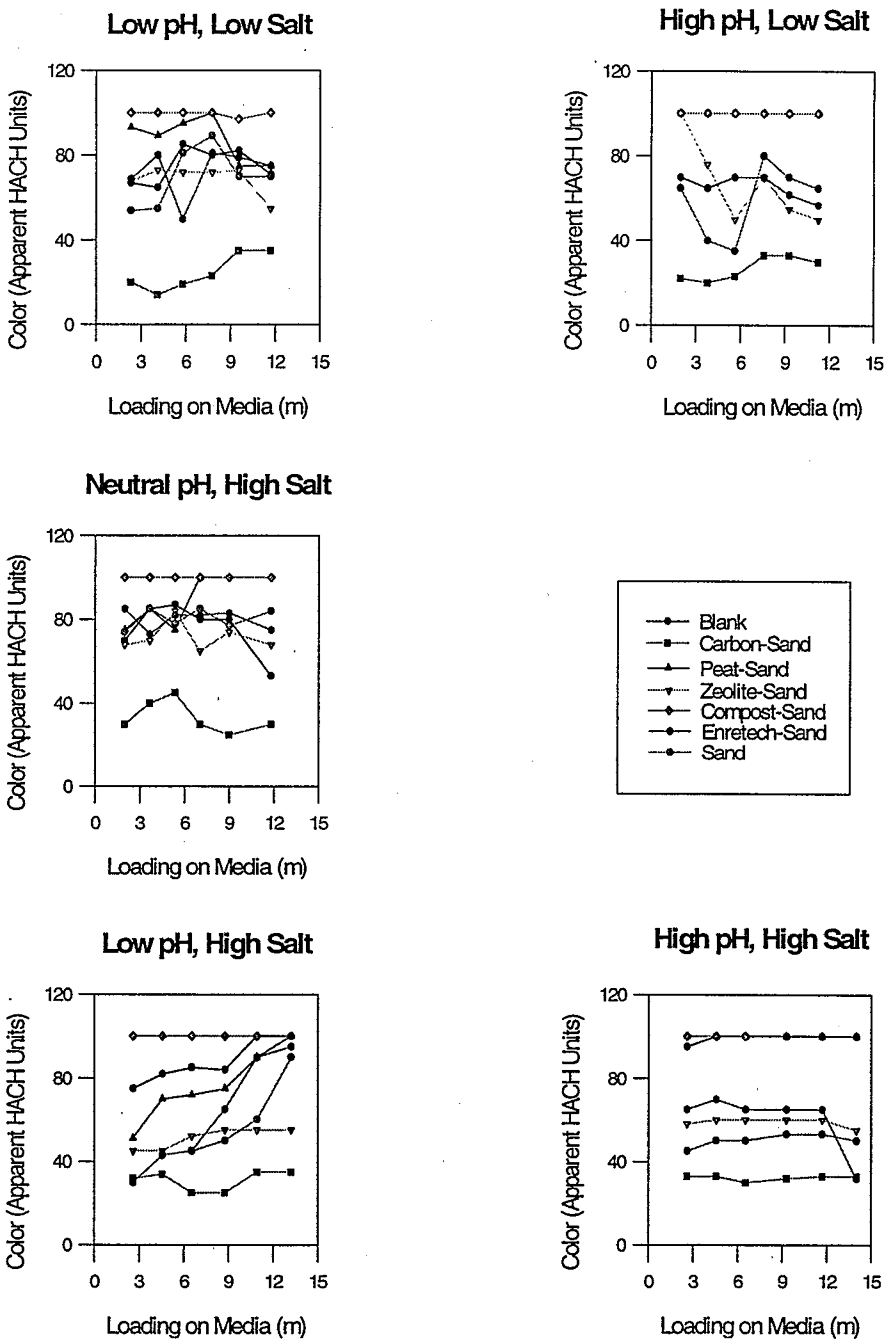
Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		2.582 m			2.582 m	
Grab #2		4.547 m			4.547 m	
Grab #3		6.512 m			6.512 m	
Grab #4		8.757 m			9.262 m	
Grab #5		10.890 m			11.676 m	
Grab #6		13.192 m			13.978 m	
Activated Carbon-Sand						
Grab #1	75	32	57	95	33	65
Grab #2	82	34	59	100	33	67
Grab #3	85	25	71	100	30	70
Grab #4	84	25	70	100	32	68
Grab #5	100	35	65	100	33	67
Grab #6	100	35	65	100	33	67
Peat-Sand						
Grab #1	75	51	32	95	100	-5
Grab #2	82	70	15	100	100	0
Grab #3	85	72	15	100	100	0
Grab #4	84	75	11	100	100	0
Grab #5	100	90	10	100	100	0
Grab #6	100	100	0	100	100	0
Zeolite-Sand						
Grab #1	75	45	40	95	58	39
Grab #2	82	45	45	100	60	40
Grab #3	85	52	39	100	60	40
Grab #4	84	55	35	100	60	40
Grab #5	100	55	45	100	60	40
Grab #6	100	55	45	100	55	45

FILTRATION MEDIA EVALUATION: Bench-Scale T

COLOR (HACH Units) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	75	100	-33	95	100	-5
Grab #2	82	100	-22	100	100	0
Grab #3	85	100	-18	100	100	0
Grab #4	84	100	-19	100	no sample	N/A
Grab #5	100	100	0	100	no sample	N/A
Grab #6	100	no sample	N/A	100	no sample	N/A
Enretech-Sand						
Grab #1	75	30	60	95	65	32
Grab #2	82	32	61	100	70	30
Grab #3	85	40	53	100	65	35
Grab #4	84	65	23	100	65	35
Grab #5	100	90	10	100	65	35
Grab #6	100	95	5	100	65	35
Sand						
Grab #1	75	30	60	95	45	53
Grab #2	82	43	48	100	50	50
Grab #3	85	45	47	100	50	50
Grab #4	84	50	40	100	53	47
Grab #5	100	60	40	100	53	47
Grab #6	100	90	10	100	50	50



COLOR: Bench-Scale Testing

CONTRAST TABLE EFFLUENT QUALITY COLOR

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	24	6	4
2	1	-1	-1	27	6	2
3	-1	1	-1	31	6	2
4	1	1	1	32	6	0
Effect	2	6	-1	29		2

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	88	6	4
2	1	-1	-1	100	6	0
3	-1	1	-1	76	6	7
4	1	1	1	100	6	0
Effect	18	-6	6	91		4

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	69	6	3
2	1	-1	-1	67	6	8
3	-1	1	-1	51	6	2
4	1	1	1	59	6	1
Effect	3	-13	5	61		4

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	100	6	1
2	1	-1	-1	100	6	0
3	-1	1	-1	100	5	0
4	1	1	1	100	3	0
Effect	0	0	0	100		0

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	69	6	6
2	1	-1	-1	66	6	2
3	-1	1	-1	59	6	12
4	1	1	1	66	6	1
Effect	2	-5	5	65		7

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	70	6	6
2	1	-1	-1	59	6	7
3	-1	1	-1	53	6	8
4	1	1	1	50	6	1
Effect	-7	-13	4	58		6

CONTRAST TABLE REMOVAL EFFICIENCY COLOR

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	67	6	5.19
2	1	-1	-1	73	6	2.39
3	-1	1	-1	65	6	2.31
4	1	1	1	67	6	9.97
Effect	4.67	-4.00	-1.83	67.92		5.86

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-18	6	7.66
2	1	-1	-1	0	6	0.00
3	-1	1	-1	14	6	4.27
4	1	1	1	-1	6	0.83
Effect	1.83	15.67	-16.50	-1.33		4.40

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	8	6	5.06
2	1	-1	-1	30	6	7.96
3	-1	1	-1	36	6	1.71
4	1	1	1	41	6	0.88
Effect	13.67	19.33	-8.50	28.42		4.81

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-34	6	6.50
2	1	-1	-1	0	6	0.00
3	-1	1	-1	-18	5	5.32
4	1	1	1	-2	3	1.67
Effect	25.45	7.05	-8.72	-13.56		4.81

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	7	6	9.48
2	1	-1	-1	34	6	2.20
3	-1	1	-1	35	6	10.48
4	1	1	1	34	6	0.88
Effect	12.83	13.83	-14.50	27.58		7.16

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	7	6	4.60
2	1	-1	-1	41	6	7.24
3	-1	1	-1	41	6	6.85
4	1	1	1	50	6	0.92
Effect	21.08	21.08	-12.42	34.63		5.51

pH

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	6.88	6.57	-5	5.03	5.89	17	9.94	7.86	21
Grab #2	6.93	6.74	-3	4.98	5.77	16	10.00	8.22	18
Grab #3	6.95	6.84	-2	4.99	5.70	14	9.87	8.04	19
Grab #4	6.98	6.85	-2	5.11	6.08	19	9.85	8.62	12
Grab #5	7.05	7.09	-1	5.18	6.13	-18	9.67	8.84	9
Grab #6	6.99	6.88	-2	4.80	5.61	17	9.46	9.10	4
Peat-Sand									
Grab #1	6.88	5.32	-23	5.03	3.83	-24	9.94	6.60	34
Grab #2	6.93	5.06	-27	4.98	3.90	-22	10.00	6.32	37
Grab #3	6.95	5.29	-24	4.99	3.80	-24	9.87	6.45	35
Grab #4	6.98	5.84	-16	5.11	4.11	-20	9.85	6.49	34
Grab #5	7.05	no sample	N/A	5.18	4.31	17	9.67	6.59	32
Grab #6	6.99	no sample	N/A	4.80	4.21	-12	9.46	6.67	29
Zeolite-Sand									
Grab #1	6.88	6.74	-2	5.03	5.73	14	9.94	9.36	6
Grab #2	6.93	6.71	-3	4.98	5.44	9	10.00	9.95	1
Grab #3	6.95	6.89	-1	4.99	5.28	6	9.87	9.89	0
Grab #4	6.98	6.61	-5	5.11	5.48	7	9.85	9.88	0
Grab #5	7.05	6.51	8	5.18	5.33	-3	9.67	9.67	0
Grab #6	6.99	6.88	-2	4.80	5.64	18	9.46	9.64	-2

pH (Continued)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		1.964 m			2.302 m			1.964 m	
Grab #2		3.649 m			4.098 m			3.761 m	
Grab #3		5.333 m			5.782 m			5.614 m	
Grab #4		7.017 m			7.747 m			7.578 m	
Grab #5		8.982 m			9.543 m			9.262 m	
Grab #6		11.789 m			11.676 m			11.227 m	
Compost-Sand									
Grab #1	6.88	6.94	1	5.03	6.48	29	9.94	6.54	34
Grab #2	6.93	6.73	-3	4.98	6.33	27	10.00	7.63	24
Grab #3	6.95	7.02	1	4.99	6.25	25	9.87	8.03	19
Grab #4	6.98	6.95	0	5.11	6.54	28	9.85	7.69	22
Grab #5	7.05	6.88	2	5.18	5.68	-10	9.67	7.59	22
Grab #6	6.99	6.75	-3	4.80	6.38	33	9.46	7.74	18
Enretech-Sand									
Grab #1	6.88	6.93	1	5.03	5.57	11	9.94	9.99	-1
Grab #2	6.93	6.82	-2	4.98	5.03	1	10.00	10.15	-2
Grab #3	6.95	6.72	-3	4.99	4.98	0	9.87	10.04	-2
Grab #4	6.98	6.65	-5	5.11	4.77	-7	9.85	10.02	-2
Grab #5	7.05	6.99	1	5.18	5.05	3	9.67	9.71	0
Grab #6	6.99	6.80	-3	4.80	5.68	18	9.46	9.64	-2
Sand									
Grab #1	6.88	6.85	0	5.03	5.31	6	9.94	10.13	-2
Grab #2	6.93	6.80	-2	4.98	5.02	1	10.00	10.14	-1
Grab #3	6.95	6.84	-2	4.99	4.93	-1	9.87	10.06	-2
Grab #4	6.98	6.78	-3	5.11	5.44	6	9.85	10.03	-2
Grab #5	7.05	6.74	4	5.18	4.90	5	9.67	9.82	-2
Grab #6	6.99	6.77	-3	4.80	5.57	16	9.46	9.68	-2

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

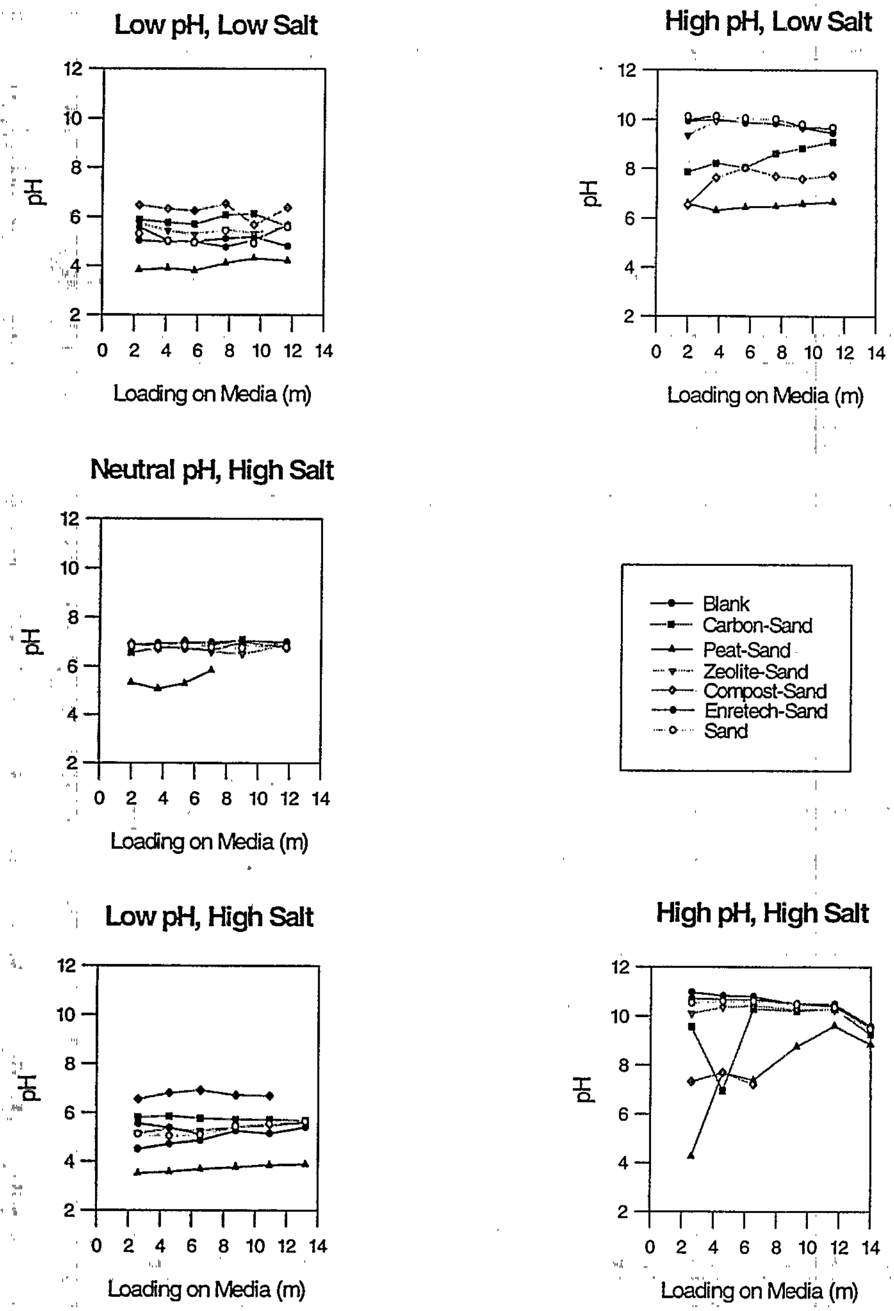
pH (Continued)

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	4.50	5.81	29	10.96	9.58	13
Grab #2	4.72	5.86	24	10.82	9.96	8
Grab #3	4.87	5.77	18	10.79	10.29	5
Grab #4	5.25	5.72	9	10.47	10.21	2
Grab #5	5.14	5.71	-11	10.41	10.29	1
Grab #6	5.41	5.68	5	9.50	9.27	2
Peat-Sand						
Grab #1	4.50	3.52	-22	10.96	4.26	61
Grab #2	4.72	3.57	-24	10.82	7.68	29
Grab #3	4.87	3.69	-24	10.79	7.37	32
Grab #4	5.25	3.77	-28	10.47	8.76	16
Grab #5	5.14	3.85	25	10.41	9.61	8
Grab #6	5.41	3.88	-28	9.50	8.85	7
Zeolite-Sand						
Grab #1	4.50	5.15	14	10.96	10.11	8
Grab #2	4.72	5.34	13	10.82	10.36	4
Grab #3	4.87	5.26	8	10.79	10.42	3
Grab #4	5.25	5.44	4	10.47	10.27	2
Grab #5	5.14	5.46	-6	10.41	10.26	1
Grab #6	5.41	5.58	3	9.50	9.49	0

pH (Continued)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		2.582 m			2.582 m	
Grab #2		4.547 m			4.547 m	
Grab #3		6.512 m			6.512 m	
Grab #4		8.757 m			9.262 m	
Grab #5		10.890 m			11.676 m	
Grab #6		13.192 m			13.978 m	
Compost-Sand						
Grab #1	4.50	6.56	46	10.96	7.32	33
Grab #2	4.72	6.81	44	10.82	7.69	29
Grab #3	4.87	6.92	42	10.79	7.20	33
Grab #4	5.25	6.72	28	10.47	no sample	N/A
Grab #5	5.14	6.69	-30	10.41	no sample	N/A
Grab #6	5.41	no sample	N/A	9.50	no sample	N/A
Enretech-Sand						
Grab #1	4.50	5.56	24	10.96	10.72	2
Grab #2	4.72	5.38	14	10.82	10.67	1
Grab #3	4.87	5.11	5	10.79	10.67	1
Grab #4	5.25	5.41	3	10.47	10.51	0
Grab #5	5.14	5.55	-8	10.41	10.50	-1
Grab #6	5.41	5.58	3	9.50	9.60	-1
Sand						
Grab #1	4.50	5.12	14	10.96	10.54	4
Grab #2	4.72	5.04	7	10.82	10.59	2
Grab #3	4.87	5.10	5	10.79	10.60	2
Grab #4	5.25	5.43	3	10.47	10.47	0
Grab #5	5.14	5.53	-8	10.41	10.36	0
Grab #6	5.41	5.65	4	9.50	9.49	0



pH: Bench-Scale Testing

COD (mg/L)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	107	64	40	62	7	89	32	0	100
Grab #2	101	63	38	70	2	97	27	0	100
Grab #3	99	62	37	71	0	100	35	0	100
Grab #4	102	63	38	74	24	68	50	0	100
Grab #5	114	66	42	75	18	76	53	0	100
Grab #6	109	75	31	69	18	74	38	0	100
Peat-Sand									
Grab #1	107	78	27	62	39	37	32	36	-13
Grab #2	101	86	15	70	47	33	27	29	-7
Grab #3	99	88	11	71	40	44	35	28	20
Grab #4	102	97	5	74	48	35	50	23	54
Grab #5	114	no sample	N/A	75	40	47	53	35	34
Grab #6	109	no sample	N/A	69	41	41	38	25	34
Zeolite-Sand									
Grab #1	107	55	49	62	35	44	32	0	100
Grab #2	101	42	58	70	37	47	27	9	67
Grab #3	99	43	57	71	42	41	35	18	49
Grab #4	102	61	40	74	35	53	50	10	80
Grab #5	114	47	59	75	35	53	53	14	74
Grab #6	109	53	51	69	19	72	38	16	58

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

COD (mg/L) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	107	89	17	62	67	-8	32	69	-116
Grab #2	101	79	22	70	38	46	27	60	-122
Grab #3	99	104	-5	71	20	72	35	30	14
Grab #4	102	111	-9	74	74	0	50	27	46
Grab #5	114	109	4	75	41	45	53	31	42
Grab #6	109	86	21	69	51	26	38	27	29
Enretech-Sand									
Grab #1	107	80	25	62	27	56	32	13	59
Grab #2	101	104	-3	70	4	94	27	8	70
Grab #3	99	89	10	71	0	100	35	17	51
Grab #4	102	88	14	74	35	53	50	41	18
Grab #5	114	87	24	75	29	61	53	48	9
Grab #6	109	76	30	69	22	68	38	75	-97
Sand									
Grab #1	107	70	35	62	41	34	32	42	-31
Grab #2	101	72	29	70	33	53	27	49	-81
Grab #3	99	59	40	71	48	32	35	45	-29
Grab #4	102	58	43	74	37	50	50	60	-20
Grab #5	114	62	46	75	39	48	53	51	4
Grab #6	109	65	40	69	37	46	38	37	3

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

COD (mg/L) (Continued)

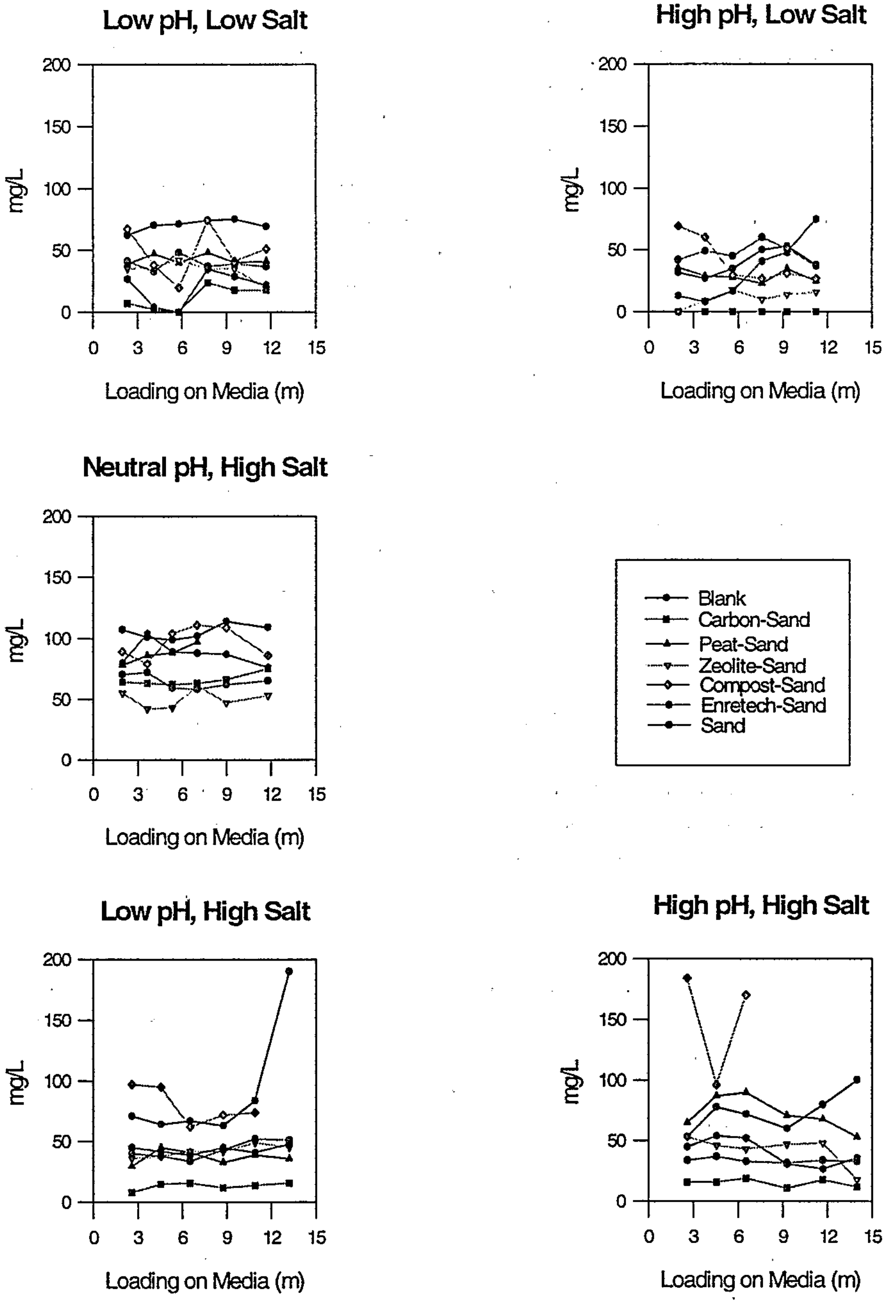
SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	71	8	89	53	16	70
Grab #2	64	15	77	78	16	79
Grab #3	67	16	76	72	19	74
Grab #4	63	12	81	60	11	82
Grab #5	84	14	83	80	18	78
Grab #6	190	16	92	100	12	88
Peat-Sand						
Grab #1	71	30	58	53	65	-23
Grab #2	64	45	30	78	87	-12
Grab #3	67	41	39	72	90	-25
Grab #4	63	33	48	60	71	-18
Grab #5	84	39	54	80	68	15
Grab #6	190	36	81	100	53	47
Zeolite-Sand						
Grab #1	71	36	49	53	53	0
Grab #2	64	38	41	78	46	41
Grab #3	67	42	37	72	43	40
Grab #4	63	42	33	60	47	22
Grab #5	84	49	42	80	48	40
Grab #6	190	45	76	100	18	82

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

Summer 1995

COD (mg/L) (Continued)

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	71	97	-37	53	184	-247
Grab #2	64	95	-48	78	96	-23
Grab #3	67	62	7	72	170	-136
Grab #4	63	72	-14	60	no sample	N/A
Grab #5	84	74	12	80	no sample	N/A
Grab #6	190	no sample	N/A	100	no sample	N/A
Enretech-Sand						
Grab #1	71	45	37	53	45	15
Grab #2	64	42	34	78	54	31
Grab #3	67	39	42	72	52	28
Grab #4	63	45	29	60	31	48
Grab #5	84	41	51	80	27	66
Grab #6	190	48	75	100	36	64
Sand						
Grab #1	71	40	44	53	34	36
Grab #2	64	38	41	78	37	53
Grab #3	67	34	49	72	33	54
Grab #4	63	43	32	60	32	47
Grab #5	84	52	38	80	34	58
Grab #6	190	51	73	100	33	67



**CHEMICAL OXYGEN DEMAND:
Bench-Scale Testing**

CONTRAST TABLE EFFLUENT QUALITY COD

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	12	6	4
2	1	-1	-1	0	6	0
3	-1	1	-1	14	6	1
4	1	1	1	15	6	1
Effect	-5	9	7	10		2

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	43	6	2
2	1	-1	-1	29	6	2
3	-1	1	-1	37	6	2
4	1	1	1	72	6	6
Effect	11	19	24	45		3

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	34	6	3
2	1	-1	-1	11	6	3
3	-1	1	-1	42	6	2
4	1	1	1	43	6	5
Effect	-11	20	12	32		3

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	49	6	8
2	1	-1	-1	41	6	8
3	-1	1	-1	80	5	7
4	1	1	1	150	3	27
Effect	31	70	39	80		11

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	20	6	6
2	1	-1	-1	34	6	11
3	-1	1	-1	43	6	1
4	1	1	1	41	6	5
Effect	6	16	-8	34		6

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	39	6	2
2	1	-1	-1	47	6	3
3	-1	1	-1	43	6	3
4	1	1	1	34	6	1
Effect	0	-5	-9	41		2

CONTRAST TABLE REMOVAL EFFICIENCY COD

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	84	6	5.39
2	1	-1	-1	100	6	0.00
3	-1	1	-1	83	6	2.62
4	1	1	1	79	6	2.55
Effect	5.75	-11.25	-10.25	86.38		3.26

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	40	6	2.22
2	1	-1	-1	20	6	10.59
3	-1	1	-1	52	6	7.19
4	1	1	1	-3	6	11.57
Effect	-36.75	-5.42	-17.58	27.21		8.70

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	52	6	4.51
2	1	-1	-1	71	6	7.30
3	-1	1	-1	46	6	6.32
4	1	1	1	38	6	11.03
Effect	5.42	-19.58	-14.25	51.71		7.67

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	30	6	12.39
2	1	-1	-1	-18	6	32.33
3	-1	1	-1	-16	5	11.79
4	1	1	1	-135	3	64.66
Effect	-83.67	-81.83	-35.67	-34.75		28.25

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	72	6	8.21
2	1	-1	-1	18	6	25.02
3	-1	1	-1	45	6	6.80
4	1	1	1	42	6	8.45
Effect	-28.17	-1.83	25.50	44.25		14.24

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	44	6	3.56
2	1	-1	-1	-26	6	12.70
3	-1	1	-1	46	6	5.85
4	1	1	1	53	6	4.26
Effect	-31.58	40.25	37.92	29.21		7.52

HARDNESS (mg/L as $CaCO_3$)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	84	84	0	74	74	0	69	49	29
Grab #2	82	77	6	89	72	19	77	43	44
Grab #3	87	72	17	83	77	7	64	47	27
Grab #4	87	77	11	123	85	31	66	45	32
Grab #5	79	77	3	85	82	4	66	56	15
Grab #6	85	76	11	84	68	19	66	56	15
Peat-Sand									
Grab #1	84	150	-79	74	58	22	69	44	36
Grab #2	82	134	-63	89	63	29	77	76	1
Grab #3	87	162	-86	83	84	-1	64	32	50
Grab #4	87	103	-18	123	77	37	66	31	53
Grab #5	79	no sample	N/A	85	74	13	66	13	80
Grab #6	85	no sample	N/A	84	79	6	66	11	83
Zeolite-Sand									
Grab #1	84	247	-194	74	86	-16	69	63	9
Grab #2	82	197	-140	89	92	-3	77	63	18
Grab #3	87	186	-114	83	93	-12	64	112	-75
Grab #4	87	191	-120	123	91	26	66	68	-3
Grab #5	79	263	-233	85	89	-5	66	82	-24
Grab #6	85	207	-144	84	100	-19	66	76	-15

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

HARDNESS (mg/L as $CaCO_3$) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	84	156	-86	74	124	-68	69	49	29
Grab #2	82	193	-135	89	130	-46	77	51	34
Grab #3	87	147	-69	83	117	-41	64	41	36
Grab #4	87	207	-138	123	156	-27	66	44	33
Grab #5	79	166	-110	85	104	-22	66	67	-2
Grab #6	85	145	-71	84	103	-23	66	52	21
Enretech-Sand									
Grab #1	84	85	-1	74	105	-42	69	65	6
Grab #2	82	78	5	89	90	-1	77	67	13
Grab #3	87	82	6	83	92	-11	64	68	-6
Grab #4	87	77	11	123	78	37	66	72	-9
Grab #5	79	81	-3	85	77	9	66	71	-8
Grab #6	85	80	6	84	78	7	66	66	0
Sand									
Grab #1	84	85	-1	74	73	1	69	53	23
Grab #2	82	134	-63	89	75	16	77	65	16
Grab #3	87	78	10	83	81	2	64	66	-3
Grab #4	87	79	9	123	84	32	66	60	9
Grab #5	79	76	4	85	80	6	66	64	3
Grab #6	85	88	-4	84	84	0	66	64	3

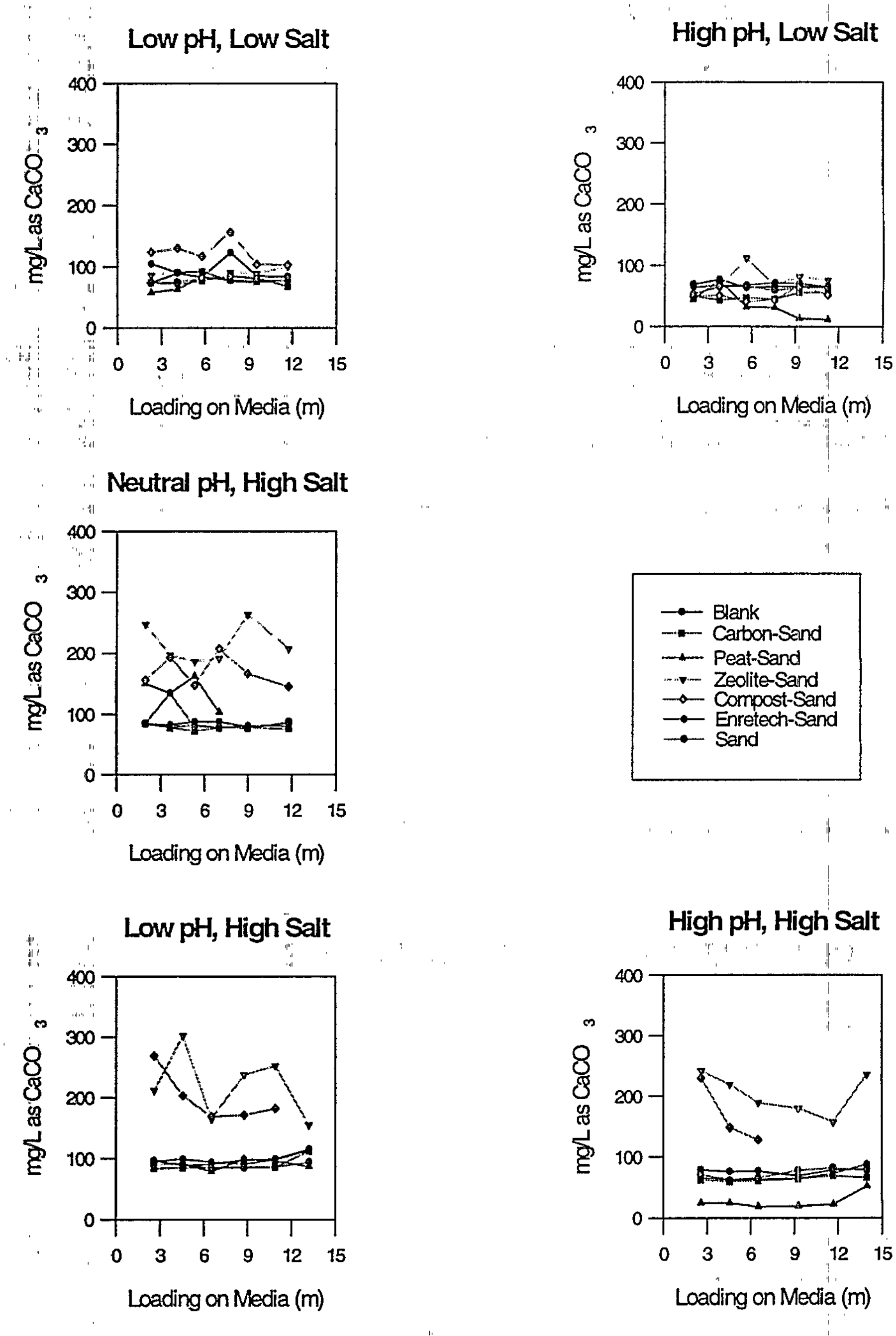
FILTRATION MEDIA EVALUATION: Bench-Scale Testing
HARDNESS (mg/L as $CaCO_3$) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	96	84	13	79	62	22
Grab #2	89	85	4	76	59	22
Grab #3	91	85	7	77	61	21
Grab #4	98	87	11	69	64	7
Grab #5	99	86	13	79	69	13
Grab #6	115	112	3	80	66	18
Peat-Sand						
Grab #1	96	96	0	79	24	70
Grab #2	89	91	-2	76	24	68
Grab #3	91	79	13	77	18	77
Grab #4	98	99	-1	69	19	72
Grab #5	99	96	3	79	22	72
Grab #6	115	87	24	80	52	35
Zeolite-Sand						
Grab #1	96	212	-121	79	242	-206
Grab #2	89	302	-239	76	219	-188
Grab #3	91	165	-81	77	189	-145
Grab #4	98	238	-143	69	180	-161
Grab #5	99	253	-156	79	157	-99
Grab #6	115	155	-35	80	236	-195

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

HARDNESS (mg/L as $CaCO_3$) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	96	269	-180	79	230	-191
Grab #2	89	203	-128	76	148	-95
Grab #3	91	169	-86	77	128	-66
Grab #4	89	171	-92	69	no sample	N/A
Grab #5	99	182	-84	79	no sample	N/A
Grab #6	115	no sample	N/A	80	no sample	N/A
Enretech-Sand						
Grab #1	96	96	0	79	66	16
Grab #2	89	99	-11	76	62	18
Grab #3	91	94	-3	77	63	18
Grab #4	89	91	-2	69	65	6
Grab #5	99	98	1	79	73	8
Grab #6	115	113	2	80	88	-10
Sand						
Grab #1	96	90	6	79	71	10
Grab #2	89	91	-2	76	62	18
Grab #3	91	85	7	77	66	14
Grab #4	98	85	13	69	78	-13
Grab #5	99	86	13	79	82	-4
Grab #6	115	94	18	80	78	3



HARDNESS: Bench-Scale Testing

CONTRAST TABLE EFFLUENT QUALITY HARDNESS

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	76	6	3
2	1	-1	-1	49	6	2
3	-1	1	-1	90	6	4
4	1	1	1	64	6	1
Effect	-27	14	0	70		3

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	73	6	4
2	1	-1	-1	35	6	10
3	-1	1	-1	91	6	3
4	1	1	1	27	6	5
Effect	-51	5	-13	56		6

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	92	6	2
2	1	-1	-1	77	6	8
3	-1	1	-1	221	6	23
4	1	1	1	204	6	14
Effect	-16	128	-1	148		14

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	122	6	8
2	1	-1	-1	51	6	4
3	-1	1	-1	199	5	19
4	1	1	1	169	3	31
Effect	-51	97	21	135		14

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	87	6	5
2	1	-1	-1	68	6	1
3	-1	1	-1	99	6	3
4	1	1	1	70	6	4
Effect	-24	7	-5	81		3

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	80	6	2
2	1	-1	-1	62	6	2
3	-1	1	-1	89	6	2
4	1	1	1	73	6	3
Effect	-17	10	1	76		2

CONTRAST TABLE REMOVAL EFFICIENCY HARDNESS

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	13	6	4.77
2	1	-1	-1	27	6	4.49
3	-1	1	-1	9	6	1.82
4	1	1	1	17	6	2.47
Effect	11.17	-7.33	-2.50	16.50		3.62

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	18	6	5.85
2	1	-1	-1	51	6	12.37
3	-1	1	-1	6	6	4.21
4	1	1	1	66	6	6.25
Effect	46.17	1.83	13.33	35.00		7.81

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-5	6	6.66
2	1	-1	-1	-15	6	13.53
3	-1	1	-1	-129	6	28.42
4	1	1	1	-166	6	16.21
Effect	-23.33	-137.50	-13.17	-78.67		18.01

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	-38	6	7.25
2	1	-1	-1	25	6	5.85
3	-1	1	-1	-114	5	18.33
4	1	1	1	-117	3	37.77
Effect	29.83	-109.33	-33.17	-61.00		14.95

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	0	6	10.62
2	1	-1	-1	-1	6	3.57
3	-1	1	-1	-2	6	1.92
4	1	1	1	9	6	4.40
Effect	5.50	4.00	6.00	1.58		6.10

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	10	6	5.10
2	1	-1	-1	9	6	3.91
3	-1	1	-1	9	6	2.87
4	1	1	1	5	6	4.77
Effect	-2.75	-2.08	-1.75	7.96		4.25

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SUSPENDED SOLIDS (mg/L)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	26	1	96	25	0	100	41	0	100
Grab #2	18	5	72	30	0	100	30	0	100
Grab #3	31	2	94	3	0	100	40	0	100
Grab #4	28	2	93	22	0	100	52	2	96
Grab #5	31	1	97	49	2	96	61	0	100
Grab #6	31	0	100	36	0	100	35	5	86
Peat-Sand									
Grab #1	26	7	73	25	4	84	41	16	61
Grab #2	18	4	78	30	0	100	30	11	63
Grab #3	31	2	94	3	2	33	40	6	85
Grab #4	28	8	71	22	5	77	52	13	75
Grab #5	31	no sample	N/A	49	0	100	61	10	84
Grab #6	31	no sample	N/A	36	1	97	35	11	69
Zeolite-Sand									
Grab #1	26	0	100	25	0	100	41	8	80
Grab #2	18	3	83	30	0	100	30	0	100
Grab #3	31	5	84	3	1	67	40	0	100
Grab #4	28	0	100	22	1	95	52	3	94
Grab #5	31	3	90	49	0	100	61	0	100
Grab #6	31	2	94	36	0	100	35	0	100

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SUSPENDED SOLIDS (mg/L) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	26	2	92	25	2	92	41	14	66
Grab #2	18	0	100	30	5	83	30	4	87
Grab #3	31	0	100	3	4	-33	40	3	93
Grab #4	28	3	89	22	0	100	52	7	87
Grab #5	31	0	100	49	1	98	61	3	95
Grab #6	31	0	100	36	1	97	35	5	86
Enretech-Sand									
Grab #1	26	10	62	25	3	88	41	2	95
Grab #2	18	2	89	30	2	93	30	4	87
Grab #3	31	3	90	3	2	33	40	4	90
Grab #4	28	0	100	22	1	95	52	4	92
Grab #5	31	1	97	49	1	98	61	1	98
Grab #6	31	0	100	36	0	100	35	2	94
Sand									
Grab #1	26	0	100	25	0	100	41	0	100
Grab #2	18	2	89	30	1	97	30	2	93
Grab #3	31	8	74	3	2	33	40	5	88
Grab #4	28	12	57	22	0	100	52	4	92
Grab #5	31	1	97	49	0	100	61	4	93
Grab #6	31	4	87	36	0	100	35	0	100

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

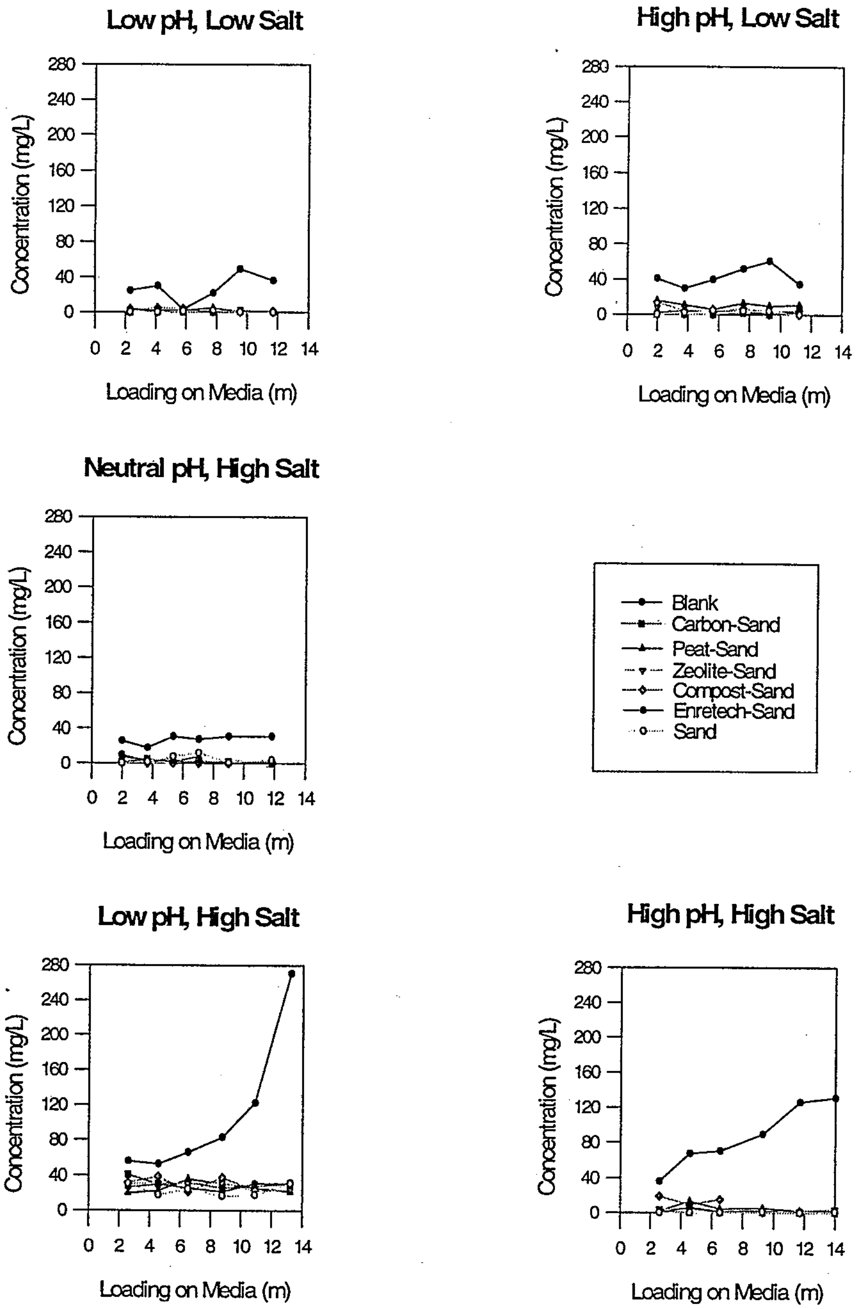
SUSPENDED SOLIDS (mg/L) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	56	41	27	36	2	94
Grab #2	53	30	43	67	0	100
Grab #3	66	32	52	70	0	100
Grab #4	83	26	69	89	0	100
Grab #5	123	28	77	126	0	100
Grab #6	271	31	89	131	0	100
Peat-Sand						
Grab #1	56	20	64	36	2	94
Grab #2	53	23	57	67	13	81
Grab #3	66	36	45	70	4	94
Grab #4	83	31	63	89	5	94
Grab #5	123	26	79	126	2	98
Grab #6	271	22	92	131	2	98
Zeolite-Sand						
Grab #1	56	30	46	36	4	89
Grab #2	53	32	40	67	4	94
Grab #3	66	31	53	70	0	100
Grab #4	83	32	61	89	0	100
Grab #5	123	23	81	126	2	98
Grab #6	271	24	91	131	4	97

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

SUSPENDED SOLIDS (mg/L) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	56	32	43	36	19	47
Grab #2	53	39	26	67	9	87
Grab #3	66	22	67	70	15	79
Grab #4	83	38	54	89	no sample	N/A
Grab #5	123	24	80	126	no sample	N/A
Grab #6	271	no sample	N/A	131	no sample	N/A
Enretech-Sand						
Grab #1	56	27	52	36	0	100
Grab #2	53	30	43	67	6	91
Grab #3	66	26	61	70	1	99
Grab #4	83	22	73	89	2	98
Grab #5	123	31	75	126	0	100
Grab #6	271	31	89	131	0	100
Sand						
Grab #1	56	31	45	36	0	100
Grab #2	53	18	66	67	0	100
Grab #3	66	25	62	70	0	100
Grab #4	83	17	80	89	1	99
Grab #5	123	18	85	126	0	100
Grab #6	271	32	88	131	1	99



SUSPENDED SOLIDS: Bench-Scale Testing

CONTRAST TABLE EFFLUENT QUALITY SUSPENDED SOLIDS

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	0.33	6	0.33
2	1	-1	-1	1.17	6	0.83
3	-1	1	-1	31.33	6	2.12
4	1	1	1	0.33	6	0.33
Effect	-15.08	15.08	-15.92	8.29		1.16

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	2.00	6	0.86
2	1	-1	-1	11.17	6	1.35
3	-1	1	-1	26.33	6	2.49
4	1	1	1	4.67	6	1.74
Effect	-6	9	-15	11.04		1.72

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	0.33	6	0.21
2	1	-1	-1	1.83	6	0.21
3	-1	1	-1	28.67	6	1.67
4	1	1	1	2.33	6	0.80
Effect	-12	14	-14	8.29		0.94

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	2.17	6	0.79
2	1	-1	-1	6.00	6	1.71
3	-1	1	-1	31.00	5	3.49
4	1	1	1	14.33	3	2.91
Effect	-6	19	-10	13.38		2.24

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	1.50	6	0.43
2	1	-1	-1	2.83	6	0.54
3	-1	1	-1	27.83	6	1.45
4	1	1	1	1.50	6	0.96
Effect	-13	13	-14	8.42		0.93

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	0.50	6	0.34
2	1	-1	-1	2.50	6	0.89
3	-1	1	-1	23.50	6	2.79
4	1	1	1	0.33	6	0.21
Effect	-11	10	-13	6.71		1.48

CONTRAST TABLE REMOVAL EFFICIENCY SUSPENDED SOLIDS

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	99	6	0.67
2	1	-1	-1	97	6	2.29
3	-1	1	-1	60	6	9.40
4	1	1	1	99	6	1.00
Effect	18.58	-18.92	20.92	88.71		4.88

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	82	6	10.49
2	1	-1	-1	73	6	4.20
3	-1	1	-1	67	6	6.78
4	1	1	1	93	6	2.56
Effect	8.75	2.58	17.75	78.63		6.71

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	94	6	5.40
2	1	-1	-1	96	6	3.28
3	-1	1	-1	62	6	8.21
4	1	1	1	96	6	1.73
Effect	18.17	-15.50	16.17	86.92		5.25

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	73	6	21.31
2	1	-1	-1	86	6	4.21
3	-1	1	-1	54	5	9.35
4	1	1	1	71	3	12.22
Effect	14.92	-16.75	2.08	70.88		14.49

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	85	6	10.44
2	1	-1	-1	94	6	1.58
3	-1	1	-1	66	6	6.85
4	1	1	1	98	6	1.44
Effect	21.17	-7.67	11.33	85.58		6.33

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	88	6	11.08
2	1	-1	-1	94	6	1.94
3	-1	1	-1	71	6	6.70
4	1	1	1	100	6	0.21
Effect	17.33	-6.00	11.33	88.33		6.55

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

Summer 1995

PSD (6 to 8 µm) (μm^3/mL)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	13,050,195	90,362	99	3,349,404	367,909	89	4,000,473	123,661	97
Grab #2	1,353,569	100,057	93	3,378,835	78,376	98	3,449,967	74,164	98
Grab #3	1,411,945	83,067	94	3,180,618	41,200	99	4,179,812	122,081	97
Grab #4	1,249,351	56,684	95	2,994,856	88,109	97	4,696,555	75,303	98
Grab #5	820,607	50,676	94	3,967,999	38,177	99	5,587,359	52,325	99
Grab #6	1,257,551	38,000	97	3,090,318	446,005	86	3,306,486	38,954	99
Peat-Sand									
Grab #1	13,050,195	93,169	99	3,349,404	331,414	90	4,000,473	1,502,911	62
Grab #2	1,353,569	64,865	95	3,378,835	124,405	96	3,449,967	1,180,587	66
Grab #3	1,411,945	85,073	94	3,180,618	88,637	97	4,179,812	812,519	81
Grab #4	1,249,351	86,912	93	2,994,856	164,825	94	4,696,555	1,874,281	60
Grab #5	820,607	no sample	N/A	3,967,999	186,069	95	5,587,359	1,290,264	77
Grab #6	1,257,551	no sample	N/A	3,090,318	176,540	94	3,306,486	551,385	83
Zeolite-Sand									
Grab #1	13,050,195	185,941	99	3,349,404	66,317	98	4,000,473	126,871	97
Grab #2	1,353,569	46,811	97	3,378,835	117,945	97	3,449,967	68,322	98
Grab #3	1,411,945	149,617	89	3,180,618	47,849	98	4,179,812	472,294	89
Grab #4	1,249,351	104,816	92	2,994,856	51,471	98	4,696,555	91,125	98
Grab #5	820,607	170,556	79	3,967,999	28,781	99	5,587,359	93,781	98
Grab #6	1,257,551	152,459	88	3,090,318	54,360	98	3,306,486	34,722	99

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

PSD (6 to 8 µm) (µm^3/mL) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		1.964 m			2.302 m			1.964 m	
Grab #2		3.649 m			4.098 m			3.761 m	
Grab #3		5.333 m			5.782 m			5.614 m	
Grab #4		7.017 m			7.747 m			7.578 m	
Grab #5		8.982 m			9.543 m			9.262 m	
Grab #6		11.789 m			11.676 m			11.227 m	
Compost-Sand									
Grab #1	13,050,195	635,485	95	3,349,404	311,286	91	4,000,473	3,090,779	23
Grab #2	1,353,569	146,224	89	3,378,835	3,267,402	3	3,449,967	1,095,584	68
Grab #3	1,411,945	272,768	81	3,180,618	900,626	72	4,179,812	2,840,835	32
Grab #4	1,249,351	277,088	78	2,994,856	285,603	90	4,696,555	1,481,503	68
Grab #5	820,607	190,010	77	3,967,999	222,775	94	5,587,359	360,882	94
Grab #6	1,257,551	100,020	92	3,090,318	242,059	92	3,306,486	197,384	94
Enretech-Sand									
Grab #1	13,050,195	234,128	98	3,349,404	118,675	96	4,000,473	300,317	92
Grab #2	1,353,569	401,031	70	3,378,835	320,506	91	3,449,967	43,969	99
Grab #3	1,411,945	437,401	69	3,180,618	122,205	96	4,179,812	87,542	98
Grab #4	1,249,351	458,880	63	2,994,856	107,530	96	4,696,555	79,645	98
Grab #5	820,607	227,397	72	3,967,999	155,226	96	5,587,359	220,756	96
Grab #6	1,257,551	151,599	88	3,090,318	183,243	94	3,306,486	86,402	97
Sand									
Grab #1	13,050,195	696,404	95	3,349,404	65,912	98	4,000,473	97,273	98
Grab #2	1,353,569	420,605	69	3,378,835	218,071	94	3,449,967	7,753	100
Grab #3	1,411,945	659,557	53	3,180,618	76,521	98	4,179,812	23,244	99
Grab #4	1,249,351	458,826	63	2,994,856	240,489	92	4,696,555	94,958	98
Grab #5	820,607	163,392	80	3,967,999	57,298	99	5,587,359	100,018	98
Grab #6	1,257,551	88,022	93	3,090,318	126,709	96	3,306,486	73,434	98

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

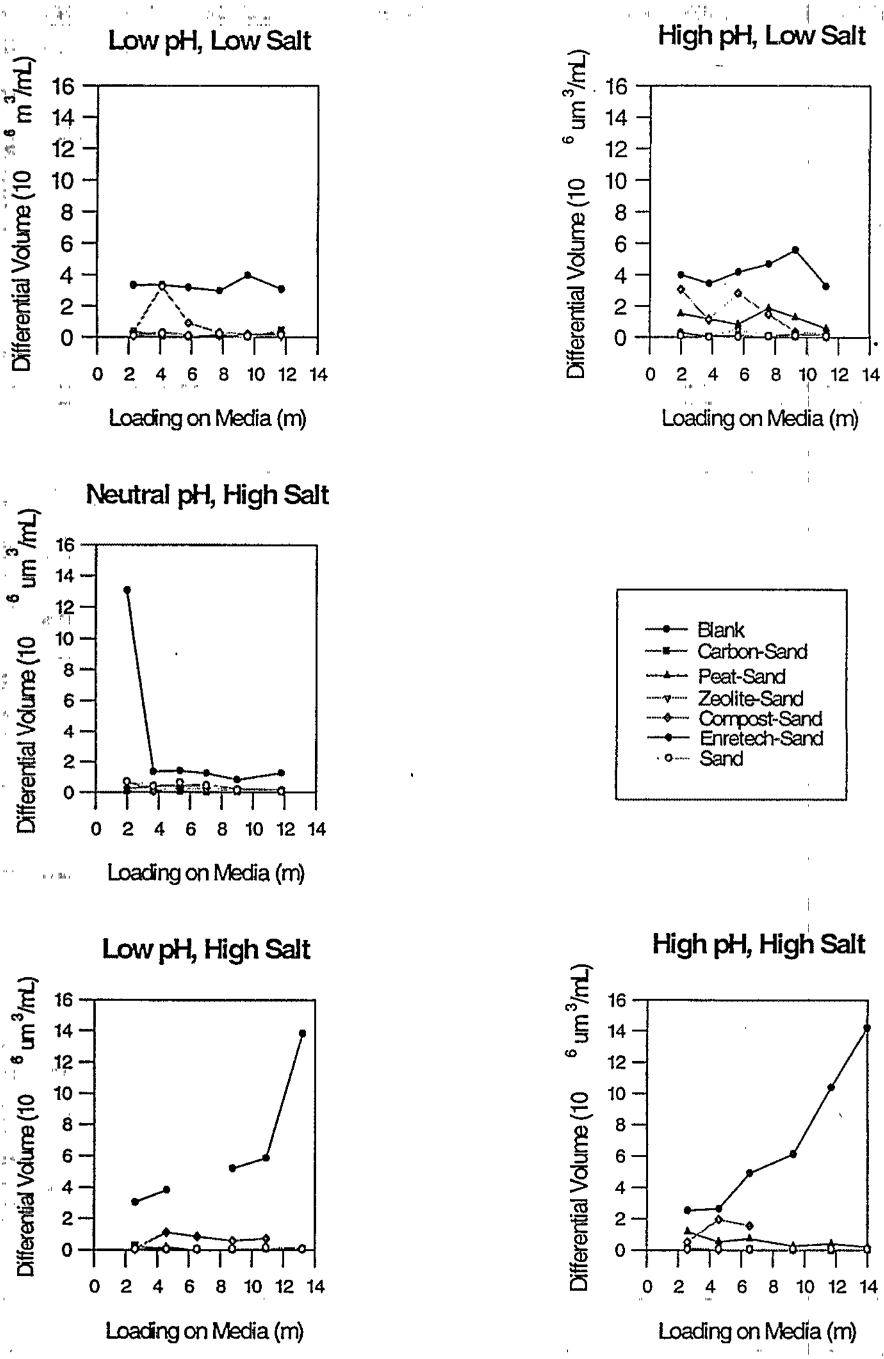
PSD (6 to 8 μm) (μm^3/mL) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	3,030,762	269,514	91	2,505,241	109,905	96
Grab #2	3,814,897	48,544	99	2,624,299	80,107	97
Grab #3		34,780	N/A	4,879,849	34,799	99
Grab #4	5,185,203	45,427	99	6,108,748	27,654	100
Grab #5	5,850,082	74,808	99	10,383,809	14,618	100
Grab #6	13,806,102	54,446	100	14,186,534	40,384	100
Peat-Sand						
Grab #1	3,030,762	48,896	98	2,505,241	1,146,643	54
Grab #2	3,814,897	147,951	96	2,624,299	521,909	80
Grab #3		36,842	N/A	4,879,849	712,446	85
Grab #4	5,185,203	55,795	99	6,108,748	247,869	96
Grab #5	5,850,082	98,513	98	10,383,809	393,288	96
Grab #6	13,806,102	48,487	100	14,186,534	186,263	99
Zeolite-Sand						
Grab #1	3,030,762	31,791	99	2,505,241	32,817	99
Grab #2	3,814,897	44,382	99	2,624,299	28,782	99
Grab #3		37,332	N/A	4,879,849	37,148	99
Grab #4	5,185,203	60,501	99	6,108,748	13,485	100
Grab #5	5,850,082	105,724	98	10,383,809	17,973	100
Grab #6	13,806,102	84,658	99	14,186,534	29,400	100

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

PSD (6 to 8 μm) (μm^3/mL) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		2.582 m			2.582 m	
Grab #2		4.547 m			4.547 m	
Grab #3		6.512 m			6.512 m	
Grab #4		8.757 m			9.262 m	
Grab #5		10.890 m			11.676 m	
Grab #6		13.192 m			13.978 m	
Compost-Sand						
Grab #1	3,030,762	694,496	77	2,505,241	509,822	80
Grab #2	3,814,897	1,096,019	71	2,624,299	1,937,213	26
Grab #3		829,291	N/A	4,879,849	1,535,131	69
Grab #4	5,185,203	563,416	89	6,108,748	no sample	N/A
Grab #5	5,850,082	693,968	88	10,383,809	no sample	N/A
Grab #6	13,806,102	no sample	N/A	14,186,534	no sample	N/A
Enretech-Sand						
Grab #1	3,030,762	23,504	99	2,505,241	53,051	98
Grab #2	3,814,897	79,675	98	2,624,299	36,748	99
Grab #3		28,709	N/A	4,879,849	81,941	98
Grab #4	5,185,203	82,582	98	6,108,748	55,384	99
Grab #5	5,850,082	146,731	97	10,383,809	19,210	100
Grab #6	13,806,102	111,265	99	14,186,534	23,247	100
Sand						
Grab #1	3,030,762	24,213	99	2,505,241	41,392	98
Grab #2	3,814,897	61,137	98	2,624,299	49,690	98
Grab #3		46,633	N/A	4,879,849	47,656	99
Grab #4	5,185,203	65,056	99	6,108,748	79,793	99
Grab #5	5,850,082	157,551	97	10,383,809	77,692	99
Grab #6	13,806,102	60,360	100	14,186,534	46,179	100



PARTICLE SIZE DISTRIBUTION: Bench-Scale Testing
(6 to 8 µm)

CONTRAST TABLE FINAL EFFLUENT PSD (6 to 8 μm)

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	176629	6	73971
2	1	-1	-1	81081	6	14349
3	-1	1	-1	87920	6	36719
4	1	1	1	51245	6	14788
Effect	-66112	-59273	29436	99219		42558

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	178648	6	33977
2	1	-1	-1	1201991	6	193714
3	-1	1	-1	72747	6	18994
4	1	1	1	534736	6	144903
Effect	742666	-386578	-280677	497031		122513

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	61121	6	12405
2	1	-1	-1	144519	6	66073
3	-1	1	-1	60731	6	11901
4	1	1	1	22191	6	3692
Effect	22429	-61359	-60970	72140		34186

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	871625	6	490420
2	1	-1	-1	1511161	6	499532
3	-1	1	-1	775437	5	90503
4	1	1	1	1327389	3	424943
Effect	595744	-139980	-43792	1121403		446494

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	167898	6	32578
2	1	-1	-1	136439	6	41084
3	-1	1	-1	78744	6	19365
4	1	1	1	44930	6	9563
Effect	-32637	-90331	-1178	107003		28354

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	130833	6	32774
2	1	-1	-1	66113	6	16583
3	-1	1	-1	69158	6	18833
4	1	1	1	57067	6	6950
Effect	-38406	-35361	26314	80793		20929

CONTRAST TABLE REMOVAL EFFICIENCY PSD (6 to 8 µm)

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	95	6	2.32
2	1	-1	-1	98	6	0.37
3	-1	1	-1	98	5	1.66
4	1	1	1	99	6	0.71
Effect	2.20	1.80	-1.13	97.23		1.47

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	94	6	0.99
2	1	-1	-1	72	6	4.10
3	-1	1	-1	98	5	0.66
4	1	1	1	85	6	6.89
Effect	-18.02	8.68	4.82	87.26		4.24

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	98	6	0.26
2	1	-1	-1	97	6	1.52
3	-1	1	-1	99	5	0.20
4	1	1	1	100	6	0.22
Effect	-0.40	1.90	1.10	98.20		0.82

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	74	6	14.51
2	1	-1	-1	63	6	12.29
3	-1	1	-1	81	4	4.37
4	1	1	1	58	3	16.48
Effect	-16.71	1.38	-6.21	69.10		12.14

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	95	6	0.83
2	1	-1	-1	97	6	1.02
3	-1	1	-1	98	5	0.37
4	1	1	1	99	6	0.37
Effect	1.32	2.85	-0.52	97.18		0.73

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	96	6	1.11
2	1	-1	-1	99	6	0.34
3	-1	1	-1	99	5	0.51
4	1	1	1	99	6	0.31
Effect	1.28	1.38	-1.05	98.03		0.67

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

PSD (20 to 22 μm) (μm^3/mL)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	707,953	46,508	93	1,782,999	46,860	97	1,996,424	109,482	95
Grab #2	1,015,049	46,171	95	1,953,352	50,395	97	1,479,264	52,241	96
Grab #3	1,606,916	66,049	96	2,146,941	45,835	98	2,062,733	72,279	96
Grab #4	1,707,513	25,301	99	2,462,233	36,832	99	2,374,959	34,298	99
Grab #5	1,156,495	30,774	97	2,660,391	12,473	100	2,895,904	23,747	99
Grab #6	1,421,397	38,109	97	2,174,088	1,134,469	48	1,656,176	18,371	99
Peat-Sand									
Grab #1	707,953	143,232	80	1,782,999	23,887	99	1,996,424	184,283	91
Grab #2	1,015,049	40,187	96	1,953,352	41,738	98	1,479,264	128,556	91
Grab #3	1,606,916	114,206	93	2,146,941	71,138	97	2,062,733	173,955	92
Grab #4	1,707,513	237,075	86	2,462,233	96,103	96	2,374,959	165,121	93
Grab #5	1,156,495	no sample	N/A	2,660,391	131,136	95	2,895,904	221,463	92
Grab #6	1,421,397	no sample	N/A	2,174,088	36,264	98	1,656,176	108,108	93
Zeolite-Sand									
Grab #1	707,953	62,877	91	1,782,999	26,424	99	1,996,424	169,210	92
Grab #2	1,015,049	76,565	92	1,953,352	72,473	96	1,479,264	136,050	91
Grab #3	1,606,916	112,835	93	2,146,941	16,075	99	2,062,733	115,413	94
Grab #4	1,707,513	98,767	94	2,462,233	13,749	99	2,374,959	429,971	82
Grab #5	1,156,495	39,976	97	2,660,391	26,404	99	2,895,904	75,894	97
Grab #6	1,421,397	40,308	97	2,174,088	25,030	99	1,656,176	23,468	99

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

PSD (20 to 22 µm) ($\mu m^3/mL$) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	707,953	316,480	55	1,782,999	76,319	96	1,996,424	224,812	89
Grab #2	1,015,049	41,259	96	1,953,352	141,238	93	1,479,264	178,962	88
Grab #3	1,606,916	154,271	90	2,146,941	37,603	98	2,062,733	28,925	99
Grab #4	1,707,513	112,739	93	2,462,233	44,037	98	2,374,959	50,860	98
Grab #5	1,156,495	113,456	90	2,660,391	52,637	98	2,895,904	34,292	99
Grab #6	1,421,397	93,024	93	2,174,088	70,078	97	1,656,176	11,467	99
Enretech-Sand									
Grab #1	707,953	81,778	88	1,782,999	80,205	96	1,996,424	22,476	99
Grab #2	1,015,049	52,687	95	1,953,352	56,192	97	1,479,264	53,120	96
Grab #3	1,606,916	37,896	98	2,146,941	28,747	99	2,062,733	39,105	98
Grab #4	1,707,513	51,009	97	2,462,233	61,723	97	2,374,959	65,817	97
Grab #5	1,156,495	48,564	96	2,660,391	9,844	100	2,895,904	53,890	98
Grab #6	1,421,397	66,338	95	2,174,088	26,152	99	1,656,176	56,656	97
Sand									
Grab #1	707,953	67,487	90	1,782,999	35,868	98	1,996,424	85,136	96
Grab #2	1,015,049	46,307	95	1,953,352	136,544	93	1,479,264	32,797	98
Grab #3	1,606,916	89,640	94	2,146,941	21,815	99	2,062,733	47,446	98
Grab #4	1,707,513	47,571	97	2,462,233	95,033	96	2,374,959	66,254	97
Grab #5	1,156,495	53,344	95	2,660,391	34,041	99	2,895,904	47,663	98
Grab #6	1,421,397	26,829	98	2,174,088	35,019	98	1,656,176	69,182	96

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

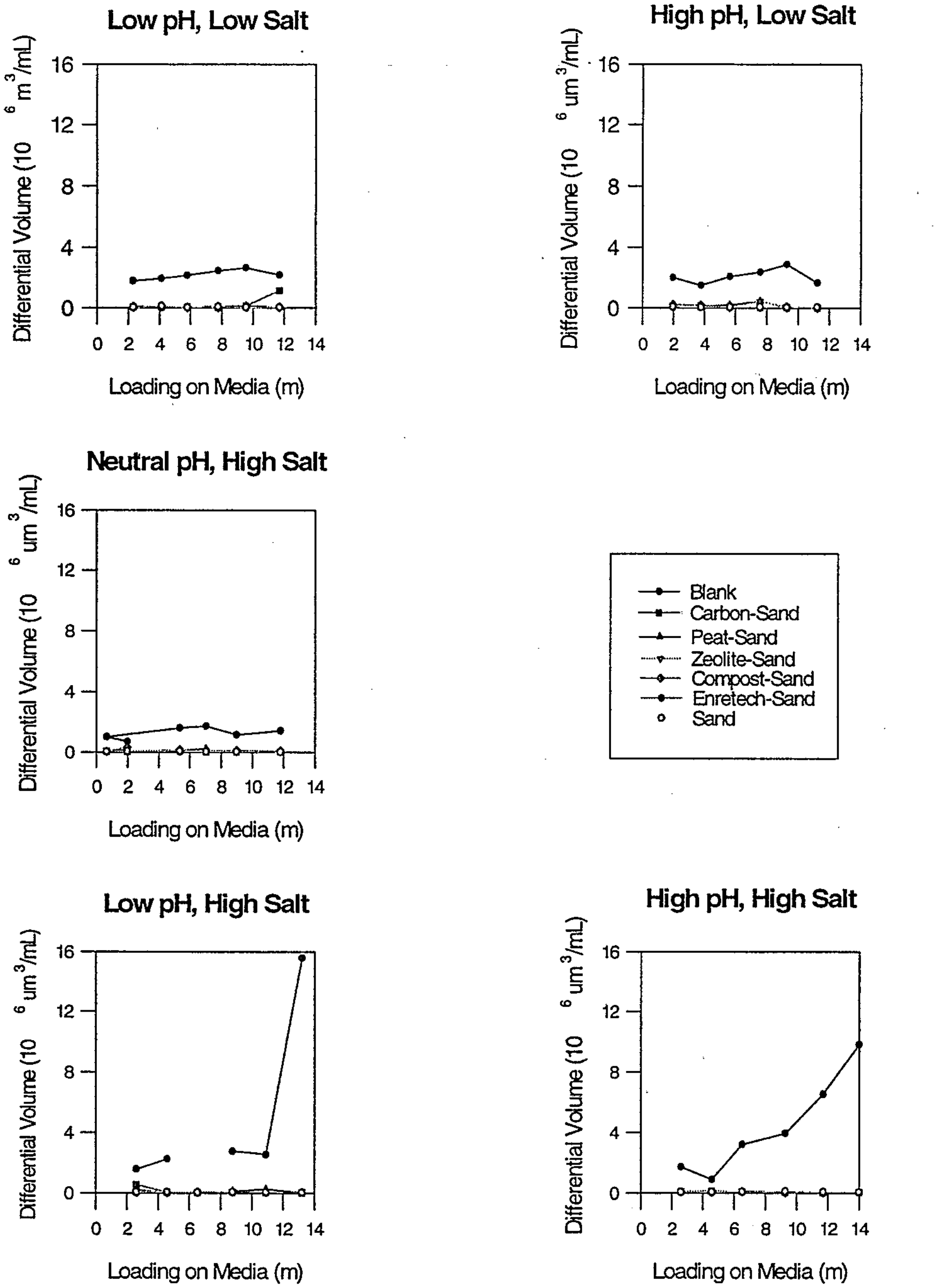
PSD (20 to 22 μm) (μm^3/mL) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		2.582 m			2.582 m	
Grab #2		4.547 m			4.547 m	
Grab #3		6.512 m			6.512 m	
Grab #4		8.757 m			9.262 m	
Grab #5		10.890 m			11.676 m	
Grab #6		13.192 m			13.978 m	
Activated Carbon-Sand						
Grab #1	1,573,806	538,507	66	1,731,594	93,842	95
Grab #2	2,252,125	44,071	98	1,884,167	128,668	93
Grab #3		15,788	N/A	2,319,504	75,854	97
Grab #4	2,782,294	66,864	98	3,967,002	49,088	99
Grab #5	2,576,846	52,542	98	6,525,686	24,280	100
Grab #6	15,579,806	17,244	100	9,805,693	51,033	99
Peat-Sand						
Grab #1	1,573,806	42,412	97	1,731,594	61,969	96
Grab #2	2,252,125	65,285	97	1,884,167	76,578	96
Grab #3		47,214	N/A	2,319,504	93,863	96
Grab #4	2,782,294	125,113	96	3,967,002	103,535	97
Grab #5	2,576,846	262,589	90	6,525,686	79,104	99
Grab #6	15,579,806	30,695	100	9,805,693	57,432	99
Zeolite-Sand						
Grab #1	1,573,806	36,957	98	1,731,594	74,260	96
Grab #2	2,252,125	33,037	99	1,884,167	58,772	97
Grab #3		36,851	N/A	2,319,504	193,988	92
Grab #4	2,782,294	102,414	96	3,967,002	14,589	100
Grab #5	2,576,846	71,939	97	6,525,686	32,004	100
Grab #6	15,579,806	98,216	99	9,805,693	62,432	99

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

PSD (20 to 22 μm) ($\mu m^3/mL$) (Continued)   Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		2.582 m			2.582 m	
Grab #2		4.547 m			4.547 m	
Grab #3		6.512 m			6.512 m	
Grab #4		8.757 m			9.262 m	
Grab #5		10.890 m			11.676 m	
Grab #6		13.192 m			13.978 m	
Compost-Sand						
Grab #1	1,573,806	191,758	88	1,731,594	61,102	96
Grab #2	2,252,125	31,823	99	1,884,167	52,235	97
Grab #3		83,909	N/A	2,319,504	71,519	97
Grab #4	2,782,294	64,886	98	3,967,002	no sample	N/A
Grab #5	2,576,846	50,978	98	6,525,686	no sample	N/A
Grab #6	15,579,806	no sample	N/A	9,805,693	no sample	N/A
Enretech-Sand						
Grab #1	1,573,806	16,974	99	1,731,594	66,214	96
Grab #2	2,252,125	28,235	99	1,884,167	17,001	99
Grab #3		31,724	N/A	2,319,504	127,283	95
Grab #4	2,782,294	53,520	98	3,967,002	102,846	97
Grab #5	2,576,846	38,405	99	6,525,686	28,687	100
Grab #6	15,579,806	75,328	100	9,805,693	26,916	100
Sand						
Grab #1	1,573,806	27,470	98	1,731,594	51,762	97
Grab #2	2,252,125	72,695	97	1,884,167	75,310	96
Grab #3		39,119	N/A	2,319,504	70,345	97
Grab #4	2,782,294	59,664	98	3,967,002	122,592	97
Grab #5	2,576,846	53,061	98	6,525,686	82,912	99
Grab #6	15,579,806	29,388	100	9,805,693	42,797	100



PARTICLE SIZE DISTRIBUTION: Bench-Scale Testing

(20 to 22 µm)

CONTRAST TABLE EFFLUENT QUALITY PSD (20 to 22 μm)

CARBON-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	221144	6	182751
2	1	-1	-1	51736	6	14594
3	-1	1	-1	122503	6	83600
4	1	1	1	70461	6	15200
Effect	-110725	-39958	58683	116461		101033

PEAT-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	66711	6	16752
2	1	-1	-1	163581	6	16526
3	-1	1	-1	56168	6	36082
4	1	1	1	78747	6	7265
Effect	59724	-47689	-37146	91302		21843

ZEOLITE-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	30026	6	8779
2	1	-1	-1	158334	6	58089
3	-1	1	-1	63236	6	13081
4	1	1	1	72674	6	25849
Effect	68874	-26225	-59435	81068		32752

COMPOST-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	70319	6	15426
2	1	-1	-1	88220	6	36789
3	-1	1	-1	84671	5	28096
4	1	1	1	61619	3	5573
Effect	-2576	-6124	-20477	76207		28221

ENRETECH-SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	43811	6	10547
2	1	-1	-1	48511	6	6278
3	-1	1	-1	40698	6	8500
4	1	1	1	61491	6	19890
Effect	12747	4934	8047	48628		12435

SAND						
Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	59720	6	18641
2	1	-1	-1	58080	6	7709
3	-1	1	-1	46900	6	7328
4	1	1	1	74286	6	11436
Effect	12873	1693	14514	59746		12159

CONTRAST TABLE REMOVAL EFFICIENCY PSD (20 to 22 µm)

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	90	6	8.38
2	1	-1	-1	97	6	0.76
3	-1	1	-1	92	5	6.51
4	1	1	1	97	6	1.11
Effect	6.33	1.00	-1.17	94.08		5.25

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	97	6	0.60
2	1	-1	-1	92	6	0.37
3	-1	1	-1	96	5	1.64
4	1	1	1	97	6	0.60
Effect	-2.00	2.00	3.17	95.58		0.85

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	99	6	0.50
2	1	-1	-1	93	6	2.43
3	-1	1	-1	98	5	0.58
4	1	1	1	97	6	1.26
Effect	-3.23	2.07	2.77	96.53		1.48

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	97	6	0.80
2	1	-1	-1	95	6	2.17
3	-1	1	-1	96	4	2.59
4	1	1	1	97	3	0.33
Effect	-0.21	0.21	1.13	96.10		1.68

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	98	6	0.63
2	1	-1	-1	98	6	0.43
3	-1	1	-1	99	5	0.32
4	1	1	1	98	6	0.87
Effect	-0.83	0.67	-0.33	98.08		0.62

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	97	6	0.95
2	1	-1	-1	97	6	0.40
3	-1	1	-1	98	5	0.49
4	1	1	1	98	6	0.61
Effect	-0.27	0.77	-0.27	97.55		0.66

PSD (52 to 54 µm) (µm^3/mL)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	766,366	0	100	218,468	0	100	354,641	35,931	90
Grab #2	0	0	N/A	316,998	62,366	80	226,150	0	100
Grab #3	0	0	N/A	516,766	29,546	94	558,922	0	100
Grab #4	978,898	0	100	579,934	0	100	547,959	0	100
Grab #5	349,373	0	100	576,275	0	100	770,363	0	100
Grab #6	1,894,743	0	100	451,612	32,117	93	292,947	0	100
Peat-Sand									
Grab #1	766,366	67,610	91	218,468	0	100	354,641	59,106	83
Grab #2	0	134,023	N/A	316,998	35,988	89	226,150	0	100
Grab #3	0	0	N/A	516,766	0	100	558,922	34,012	94
Grab #4	978,898	0	100	579,934	0	100	547,959	0	100
Grab #5	349,373	no sample	N/A	576,275	0	100	770,363	103,722	87
Grab #6	1,894,743	no sample	N/A	451,612	100,974	78	292,947	0	100
Zeolite-Sand									
Grab #1	766,366	0	100	218,468	0	100	354,641	64,413	82
Grab #2	0	0	N/A	316,998	0	100	226,150	101,929	55
Grab #3	0	196,554	N/A	516,766	62,737	88	558,922	34,760	94
Grab #4	978,898	0	100	579,934	30,310	95	547,959	30,470	94
Grab #5	349,373	0	100	576,275	0	100	770,363	0	100
Grab #6	1,894,743	30,454	98	451,612	0	100	292,947	0	100

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

PSD (52 to 54 μm) (μm^3/mL) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	766,366	34,935	95	218,468	0	100	354,641	0	100
Grab #2	0	34,860	N/A	316,998	0	100	226,150	0	100
Grab #3	0	68,893	N/A	516,766	0	100	558,922	30,294	95
Grab #4	978,898	30,419	97	579,934	0	100	547,959	0	100
Grab #5	349,373	34,987	90	576,275	0	100	770,363	0	100
Grab #6	1,894,743	0	100	451,612	0	100	292,947	33,067	89
Enretech-Sand									
Grab #1	766,366	35,952	95	218,468	0	100	354,641	33,865	90
Grab #2	0	0	N/A	316,998	34,820	89	226,150	65,111	71
Grab #3	0	0	N/A	516,766	35,959	93	558,922	0	100
Grab #4	978,898	102,996	89	579,934	99,855	83	547,959	33,086	94
Grab #5	349,373	0	100	576,275	29,506	95	770,363	35,782	95
Grab #6	1,894,743	0	100	451,612	30,580	93	292,947	0	100
Sand									
Grab #1	766,366	0	100	218,468	0	100	354,641	32,168	91
Grab #2	0	0	N/A	316,998	0	100	226,150	96,134	57
Grab #3	0	0	N/A	516,766	0	100	558,922	0	100
Grab #4	978,898	0	100	579,934	61,601	89	547,959	0	100
Grab #5	349,373	0	100	576,275	64,384	89	770,363	60,709	92
Grab #6	1,894,743	0	100	451,612	0	100	292,947	0	100

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

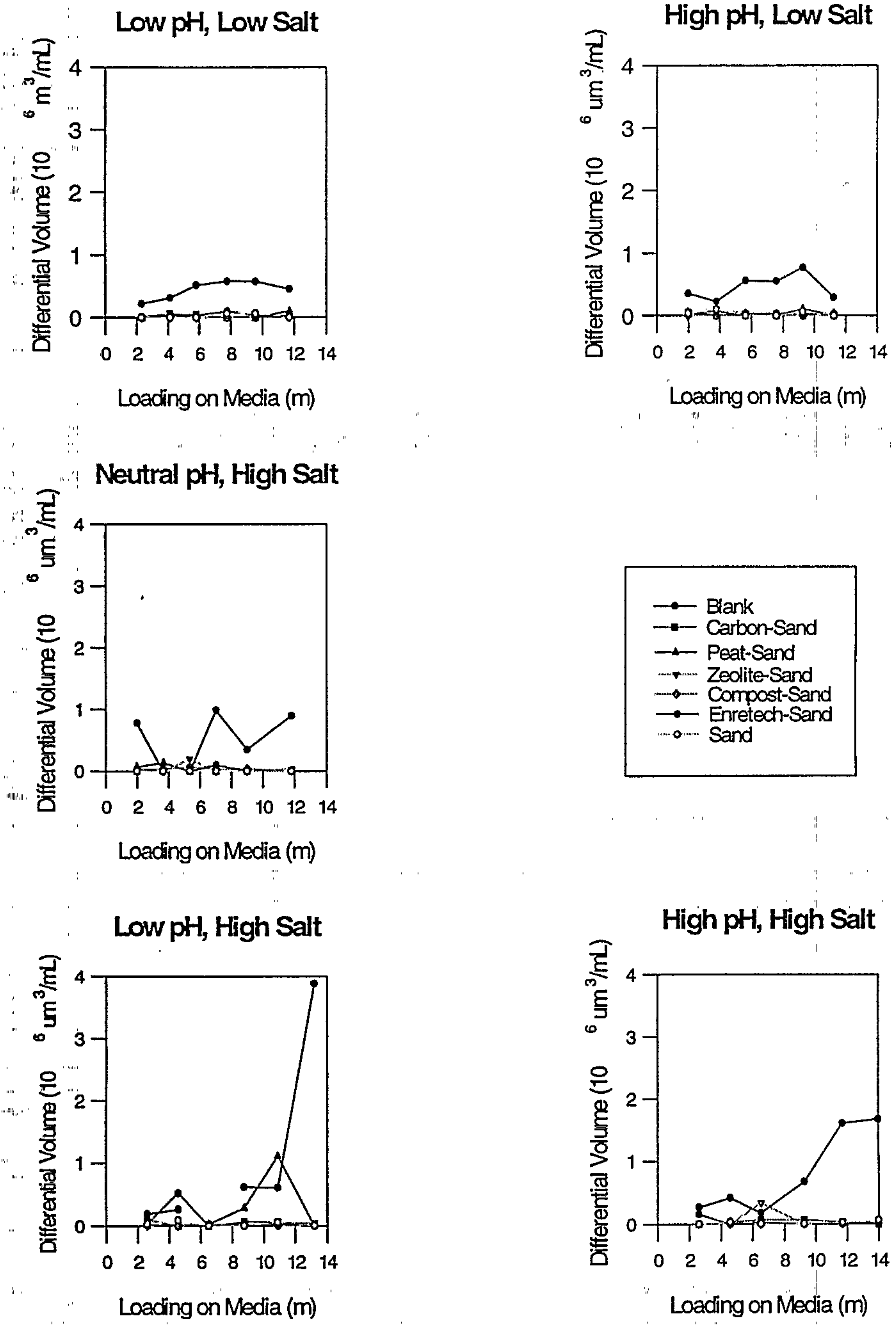
PSD (52 to 54 µm) (μm^3/mL) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	194,392	97,247	50	261,617	0	100
Grab #2	260,003	0	100	410,735	31,079	92
Grab #3		0	N/A	177,968	68,146	62
Grab #4	616,999	68,291	89	675,995	65,147	90
Grab #5	604,491	61,142	90	1,609,804	30,691	98
Grab #6	3,882,284	35,974	99	1,676,635	0	100
Peat-Sand						
Grab #1	194,392	0	100	261,617	0	100
Grab #2	260,003	0	100	410,735	0	100
Grab #3		30,421	N/A	177,968	33,960	81
Grab #4	616,999	283,448	54	675,995	0	100
Grab #5	604,491	1,111,976	-84	1,609,804	0	100
Grab #6	3,882,284	0	100	1,676,635	33,063	98
Zeolite-Sand						
Grab #1	194,392	0	100	261,617	0	100
Grab #2	260,003	30,363	88	410,735	0	100
Grab #3		30,542	N/A	177,968	334,005	-88
Grab #4	616,999	36,058	94	675,995	0	100
Grab #5	604,491	0	100	1,609,804	30,513	98
Grab #6	3,882,284	0	100	1,676,635	31,386	98

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

PSD (52 to 54 μm) (μm^3/mL) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	194,392	32,023	84	261,617	0	100
Grab #2	260,003	0	100	410,735	32,973	92
Grab #3		29,441	N/A	177,968	0	100
Grab #4	616,999	21,204	97	675,995	no sample	N/A
Grab #5	604,491	0	100	1,609,804	no sample	N/A
Grab #6	3,882,284	no sample	N/A	1,676,635	no sample	N/A
Enretech-Sand						
Grab #1	194,392	34,958	82	261,617	159,829	39
Grab #2	260,003	520,435	-100	410,735	0	100
Grab #3		0	N/A	177,968	0	100
Grab #4	616,999	0	100	675,995	0	100
Grab #5	604,491	31,250	95	1,609,804	0	100
Grab #6	3,882,284	0	100	1,676,635	0	100
Sand						
Grab #1	194,392	32,168	83	261,617	0	100
Grab #2	260,003	96,134	63	410,735	35,913	91
Grab #3		0	N/A	177,968	0	100
Grab #4	616,999	0	100	675,995	0	100
Grab #5	604,491	60,709	90	1,609,804	29,556	98
Grab #6	3,882,284	0	100	1,676,635	62,729	96



PARTICLE SIZE DISTRIBUTION: Bench-Scale Testing (52 to 54 µm)

CONTRAST TABLE EFFLUENT QUALITY PSD (52 to 54 μm)

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	20672	6	10379
2	1	-1	-1	5989	6	5989
3	-1	1	-1	43776	6	15974
4	1	1	1	32511	6	12185
Effect	-12974	24813	1709	25737		11696

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	22827	6	16698
2	1	-1	-1	32807	6	17273
3	-1	1	-1	237641	6	180640
4	1	1	1	13405	6	7066
Effect	-107128	97706	-117108	76670		91184

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	15508	6	10664
2	1	-1	-1	38595	6	16060
3	-1	1	-1	16161	6	7275
4	1	1	1	65984	6	53961
Effect	36456	14021	13368	34062		28880

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	0	6	0
2	1	-1	-1	10560	6	6688
3	-1	1	-1	16534	5	6982
4	1	1	1	10991	3	10991
Effect	2509	8482	-8051	9521		6166

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	38453	6	13429
2	1	-1	-1	27974	6	10109
3	-1	1	-1	117329	6	84792
4	1	1	1	26638	6	26638
Effect	-50585	38770	-40106	52599		45227

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	20998	6	13285
2	1	-1	-1	31502	6	16338
3	-1	1	-1	31502	6	16338
4	1	1	1	21366	6	10582
Effect	184	184	-10320	26342		14338

CONTRAST TABLE REMOVAL EFFICIENCY PSD (52 to 54 μm)

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	95	6	3.18
2	1	-1	-1	98	6	1.67
3	-1	1	-1	86	5	9.18
4	1	1	1	90	6	5.92
Effect	4	-8	0	92		5

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	95	6	3.76
2	1	-1	-1	94	6	3.04
3	-1	1	-1	54	5	35.63
4	1	1	1	97	6	3.12
Effect	21	-19	22	85		16

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	97	6	2.01
2	1	-1	-1	88	6	7.03
3	-1	1	-1	96	5	2.40
4	1	1	1	68	6	31.20
Effect	-19	-10	-9	87		17

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	100	6	0.00
2	1	-1	-1	97	6	1.86
3	-1	1	-1	95	4	3.82
4	1	1	1	97	3	2.67
Effect	0	-2	2	97		2

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	92	6	2.34
2	1	-1	-1	92	6	4.42
3	-1	1	-1	55	5	38.99
4	1	1	1	90	6	10.17
Effect	17	-19	17	82		18

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	96	6	2.32
2	1	-1	-1	90	6	6.82
3	-1	1	-1	87	5	6.85
4	1	1	1	98	6	1.45
Effect	2	-1	8	93		5

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

PSD (4 to 128 μm) (μm³/mL)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	22,840,614	1,749,065	92	21,789,488	2,973,440	86	26,876,323	1,320,120	95
Grab #2	19,630,892	745,209	96	22,106,182	1,716,523	92	18,825,206	520,590	97
Grab #3	30,264,932	1,026,342	97	23,372,882	681,225	97	25,743,796	920,221	96
Grab #4	27,765,270	927,627	97	25,315,986	551,799	98	28,367,340	607,342	98
Grab #5	19,046,744	891,149	95	28,678,916	250,748	99	38,128,020	471,973	99
Grab #6	24,369,826	1,109,584	95	24,324,454	6,647,584	73	19,363,850	268,178	99
Peat-Sand									
Grab #1	22,840,614	2,084,343	91	21,789,488	1,085,117	95	26,876,323	5,394,667	80
Grab #2	19,630,892	1,148,958	94	22,106,182	618,294	97	18,825,206	3,871,391	79
Grab #3	30,264,932	1,836,222	94	23,372,882	808,668	97	25,743,796	3,166,743	88
Grab #4	27,765,270	3,439,205	88	25,315,986	1,717,966	93	28,367,340	5,133,783	82
Grab #5	19,046,744	no sample	N/A	28,678,916	1,340,965	95	38,128,020	5,416,153	86
Grab #6	24,369,826	no sample	N/A	24,324,454	1,148,573	95	19,363,850	2,078,000	89
Zeolite-Sand									
Grab #1	22,840,614	1,490,958	93	21,789,488	669,246	97	26,876,323	1,344,978	95
Grab #2	19,630,892	944,033	95	22,106,182	1,012,317	95	18,825,206	1,326,081	93
Grab #3	30,264,932	2,446,627	92	23,372,882	1,099,948	95	25,743,796	1,863,132	93
Grab #4	27,765,270	1,684,062	94	25,315,986	301,911	99	28,367,340	810,130	97
Grab #5	19,046,744	845,045	96	28,678,916	254,725	99	38,128,020	739,801	98
Grab #6	24,369,826	883,732	96	24,324,454	817,586	97	19,363,850	377,015	98

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

PSD (4 to 128 µm) (μm^3/mL) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	22,840,614	4,098,401	82	21,789,488	1,569,581	93	26,876,323	8,412,814	69
Grab #2	19,630,892	3,438,459	82	22,106,182	7,665,187	65	18,825,206	3,368,898	82
Grab #3	30,264,932	2,110,705	93	23,372,882	2,248,914	90	25,743,796	6,282,180	76
Grab #4	27,765,270	1,742,601	94	25,315,986	1,498,921	94	28,367,340	3,469,796	88
Grab #5	19,046,744	2,024,623	89	28,678,916	1,418,336	95	38,128,020	1,335,210	96
Grab #6	24,369,826	1,109,174	95	24,324,454	949,157	96	19,363,850	868,055	96
Enretech-Sand									
Grab #1	22,840,614	1,589,767	93	21,789,488	1,076,692	95	26,876,323	590,355	98
Grab #2	19,630,892	1,728,904	91	22,106,182	1,738,690	92	18,825,206	649,548	97
Grab #3	30,264,932	1,383,406	95	23,372,882	799,739	97	25,743,796	1,091,024	96
Grab #4	27,765,270	1,775,423	94	25,315,986	1,110,026	96	28,367,340	1,388,585	95
Grab #5	19,046,744	1,624,064	91	28,678,916	843,518	97	38,128,020	1,088,760	97
Grab #6	24,369,826	1,236,237	95	24,324,454	1,039,210	96	19,363,850	687,955	96
Sand									
Grab #1	22,840,614	2,718,384	88	21,789,488	651,661	97	26,876,323	2,840,113	89
Grab #2	19,630,892	1,752,361	91	22,106,182	2,099,100	91	18,825,206	541,087	97
Grab #3	30,264,932	2,383,897	92	23,372,882	549,889	98	25,743,796	639,211	98
Grab #4	27,765,270	2,331,925	92	25,315,986	2,002,322	92	28,367,340	1,356,608	95
Grab #5	19,046,744	1,032,359	95	28,678,916	952,830	97	38,128,020	908,252	98
Grab #6	24,369,826	826,117	97	24,324,454	634,941	97	19,363,850	1,033,038	95

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

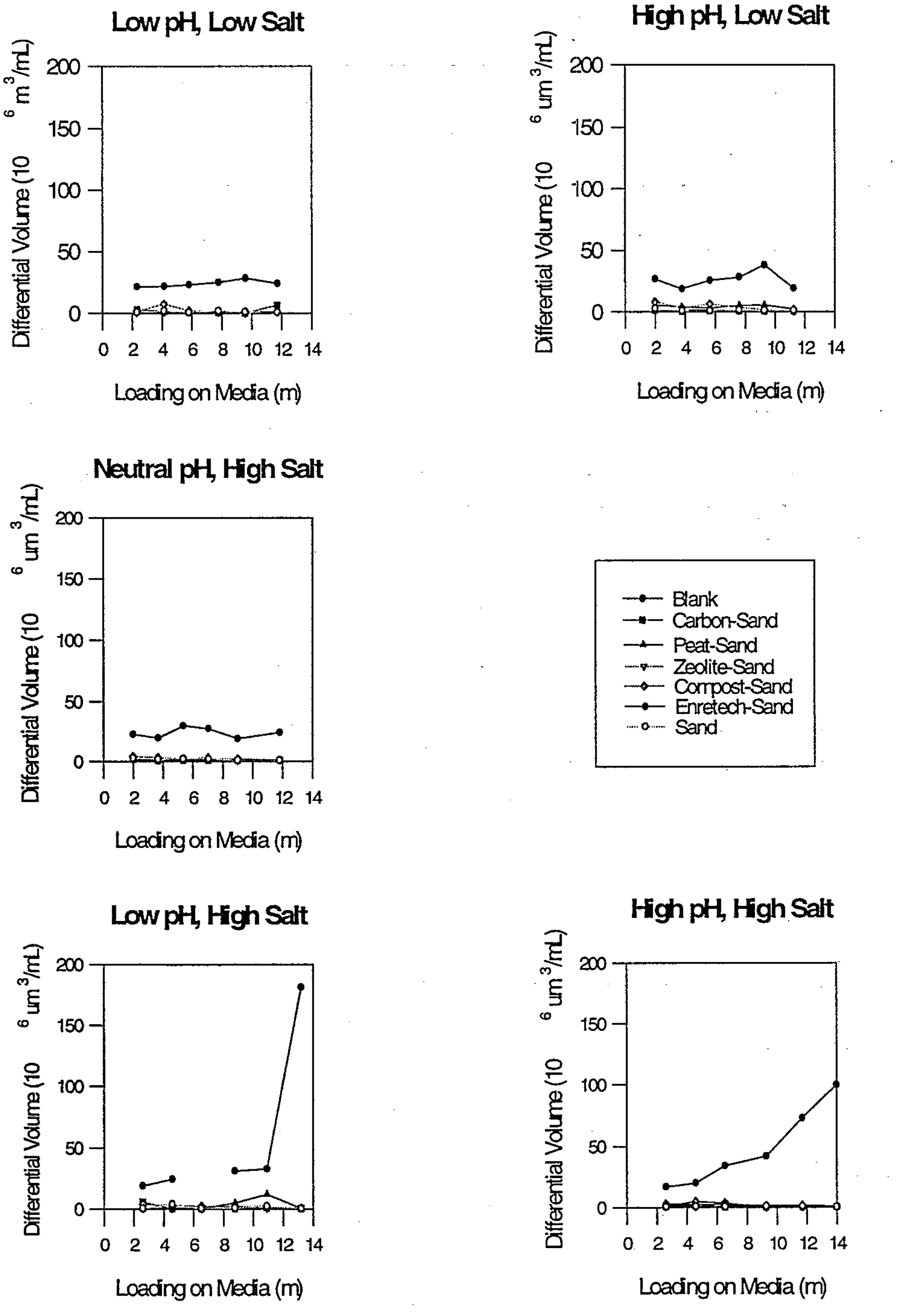
PSD (4 to 128 μm) (μm^3/mL) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	18,627,618	5,622,428	70	16,586,367	834,723	95
Grab #2	24,012,610	415,444	98	19,625,442	1,092,683	94
Grab #3		444,781	N/A	33,985,144	497,685	99
Grab #4	30,917,730	489,896	98	41,985,064	484,457	99
Grab #5	32,663,924	832,347	97	72,887,832	333,773	100
Grab #6	181,156,992	314,345	100	99,682,520	542,158	99
Peat-Sand						
Grab #1	18,627,618	548,737	97	16,586,367	2,670,987	84
Grab #2	24,012,610	894,797	96	19,625,442	2,436,873	88
Grab #3		437,505	N/A	33,985,144	2,608,785	92
Grab #4	30,917,730	4,802,549	84	41,985,064	1,531,286	96
Grab #5	32,663,924	11,749,363	64	72,887,832	1,856,752	97
Grab #6	181,156,992	317,787	100	99,682,520	867,524	99
Zeolite-Sand						
Grab #1	18,627,618	460,406	98	16,586,367	727,433	96
Grab #2	24,012,610	522,204	98	19,625,442	442,722	98
Grab #3		488,535	N/A	33,985,144	3,479,826	90
Grab #4	30,917,730	1,381,771	96	41,985,064	162,632	100
Grab #5	32,663,924	787,236	98	72,887,832	273,908	100
Grab #6	181,156,992	1,251,437	99	99,682,520	501,114	99

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

PSD (4 to 128 μm) ($\mu m^3/mL$) (Continued) Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	18,627,618	3,799,365	80	16,586,367	1,684,855	90
Grab #2	24,012,610	2,744,378	89	19,625,442	4,765,137	76
Grab #3		2,373,657	N/A	33,985,144	3,728,268	89
Grab #4	30,917,730	2,004,519	94	41,985,064	no sample	N/A
Grab #5	32,663,924	2,126,248	93	72,887,832	no sample	N/A
Grab #6	181,156,992	no sample	N/A	99,682,520	no sample	N/A
Enretech-Sand						
Grab #1	18,627,618	386,694	98	16,586,367	2,510,035	85
Grab #2	24,012,610	333,159	99	19,625,442	496,826	97
Grab #3		260,323	N/A	33,985,144	1,187,787	97
Grab #4	30,917,730	620,512	98	41,985,064	802,995	98
Grab #5	32,663,924	677,528	98	72,887,832	382,812	99
Grab #6	181,156,992	910,672	99	99,682,520	397,036	100
Sand						
Grab #1	18,627,618	300,944	98	16,586,367	481,174	97
Grab #2	24,012,610	3,945,038	84	19,625,442	688,353	96
Grab #3		376,247	N/A	33,985,144	664,128	98
Grab #4	30,917,730	800,731	97	41,985,064	1,189,638	97
Grab #5	32,663,924	2,235,539	93	72,887,832	1,119,043	98
Grab #6	181,156,992	388,966	100	99,682,520	504,518	99



PARTICLE SIZE DISTRIBUTION: Bench-Scale Testing
(4 to 128 µm)

CONTRAST TABLE EFFLUENT QUALITY PSD (4 to 128 um)

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	2136887	6	990150
2	1	-1	-1	684737	6	153936
3	-1	1	-1	1353207	6	856869
4	1	1	1	630913	6	114038
Effect	-1087221	-418752	364928	1201436		661687

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	1119931	6	158856
2	1	-1	-1	4176790	6	561351
3	-1	1	-1	3125123	6	1861073
4	1	1	1	1995368	6	290648
Effect	963552	-88115	-2093307	2604303		985954

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	692622	6	144763
2	1	-1	-1	1076856	6	218079
3	-1	1	-1	815265	6	166385
4	1	1	1	890173	6	515859
Effect	229571	-32021	-154663	868729		300961

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	2558349	6	1035450
2	1	-1	-1	4573780	6	1186863
3	-1	1	-1	2609633	5	323197
4	1	1	1	3392753	3	904887
Effect	1399275	-564871	-616155	3283629		1008874

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	1101313	6	137622
2	1	-1	-1	916038	6	130749
3	-1	1	-1	531481	6	101137
4	1	1	1	962915	6	333851
Effect	123080	-261477	308354	877937		198570

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	1148457	6	290968
2	1	-1	-1	1219718	6	345148
3	-1	1	-1	1341244	6	599776
4	1	1	1	774476	6	125111
Effect	-247754	-126228	-319015	1120974		380517

CONTRAST TABLE REMOVAL EFFICIENCY PSD (4 to 128 um)

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	91	6	4.08
2	1	-1	-1	97	6	0.67
3	-1	1	-1	93	5	5.67
4	1	1	1	98	6	1.02
Effect	5.78	1.05	-0.72	94.61		3.30

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	95	6	0.61
2	1	-1	-1	84	6	1.73
3	-1	1	-1	88	5	6.64
4	1	1	1	93	6	2.36
Effect	-3.43	0.77	7.90	90.05		3.24

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	97	6	0.61
2	1	-1	-1	96	6	0.95
3	-1	1	-1	98	5	0.49
4	1	1	1	97	6	1.56
Effect	-0.98	1.15	0.35	96.91		1.03

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	89	6	4.84
2	1	-1	-1	85	6	4.46
3	-1	1	-1	89	4	3.19
4	1	1	1	85	3	4.51
Effect	-4.17	0.33	0.17	86.83		4.23

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	96	6	0.76
2	1	-1	-1	97	6	0.43
3	-1	1	-1	98	5	0.24
4	1	1	1	96	6	2.25
Effect	-0.70	1.20	-1.70	96.60		1.27

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	95	6	1.23
2	1	-1	-1	95	6	1.38
3	-1	1	-1	94	5	2.84
4	1	1	1	98	6	0.43
Effect	1.55	0.62	1.55	95.64		1.57

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

ZINC (µg/L)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	88	13.1	85	127	52	59	117	2.5	98
Grab #2	92	15.1	84	126	51	60	121	1.6	99
Grab #3	100	27.4	73	135	76	44	109	4.4	96
Grab #4	97	32.2	67	129	48	63	138	13.3	90
Grab #5	101	19.7	80	145	78	46	159	27.6	83
Grab #6	115	14.4	87	128	73	43	107	14.4	87
Peat-Sand									
Grab #1	88	38.4	56	127	40	68	117	5.6	95
Grab #2	92	15.0	84	126	61	52	121	0.7	99
Grab #3	100	7.7	92	135	65	52	109	0.0	100
Grab #4	97	10.4	89	129	78	40	138	2.0	99
Grab #5	101	no sample	N/A	145	80	45	159	0.0	100
Grab #6	115	no sample	N/A	128	88	31	107	3.3	97
Zeolite-Sand									
Grab #1	88	7.9	91	127	8	94	117	18.2	84
Grab #2	92	15.7	83	126	16	88	121	40.3	67
Grab #3	100	27.8	72	135	28	79	109	47.0	57
Grab #4	97	32.8	66	129	33	75	138	45.9	67
Grab #5	101	14.0	86	145	14	90	159	33.3	79
Grab #6	115	3.4	97	128	4	97	107	25.5	76

ZINC (μg/L) (Continued)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	88	21.0	76	127	6	96	117	20.9	82
Grab #2	92	26.5	71	126	12	90	121	11.7	90
Grab #3	100	24.2	76	135	2	99	109	14.7	86
Grab #4	97	37.1	62	129	11	91	138	20.1	85
Grab #5	101	14.3	86	145	16	89	159	19.9	88
Grab #6	115	0.0	100	128	7	94	107	18.6	83
Enretech-Sand									
Grab #1	88	16.9	81	127	107	16	117	27.0	77
Grab #2	92	14.8	84	126	108	14	121	37.2	69
Grab #3	100	24.1	76	135	102	24	109	36.4	66
Grab #4	97	35.0	64	129	80	38	138	34.3	75
Grab #5	101	8.9	91	145	111	24	159	42.6	73
Grab #6	115	31.5	73	128	111	13	107	37.7	65
Sand									
Grab #1	88	7.0	92	127	86	32	117	25.5	78
Grab #2	92	28.4	69	126	101	20	121	46.2	62
Grab #3	100	28.9	71	135	107	21	109	34.9	68
Grab #4	97	26.1	73	129	85	34	138	53.7	61
Grab #5	101	4.2	96	145	104	29	159	61.6	61
Grab #6	115	18.3	84	128	105	18	107	37.5	65

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

ZINC (µg/L) (Continued)

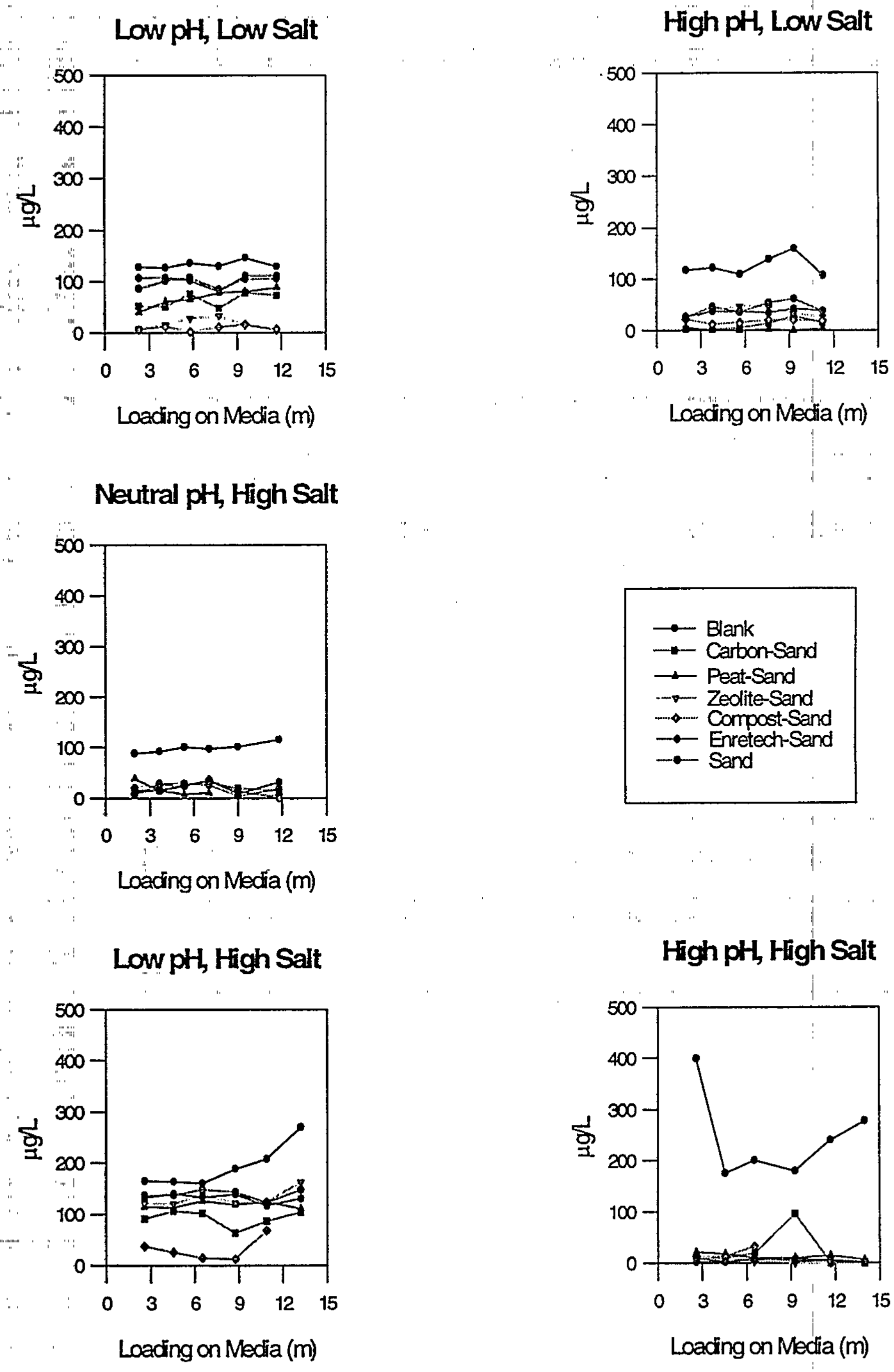
SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	164	91	45	399	8.9	98
Grab #2	163	106	35	175	10.0	94
Grab #3	160	102	36	200	18.5	91
Grab #4	188	63	66	179	95.7	46
Grab #5	207	86	58	240	0.3	100
Grab #6	270	104	61	277	0.0	100
Peat-Sand						
Grab #1	164	114	30	399	20.9	95
Grab #2	163	113	31	175	17.2	90
Grab #3	160	126	22	200	10.0	95
Grab #4	188	119	37	179	10.0	94
Grab #5	207	124	40	240	14.1	94
Grab #6	270	111	59	277	5.7	98
Zeolite-Sand						
Grab #1	164	121	26	399	4.2	99
Grab #2	163	120	26	175	9.5	95
Grab #3	160	138	14	200	2.6	99
Grab #4	188	122	35	179	0.0	100
Grab #5	207	124	40	240	0.0	100
Grab #6	270	162	40	277	1.9	99

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

Summer 1995

ZINC (μg/L) (Continued)

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1		2.582 m			2.582 m	
Grab #2		4.547 m			4.547 m	
Grab #3		6.512 m			6.512 m	
Grab #4		8.757 m			9.262 m	
Grab #5		10.890 m			11.676 m	
Grab #6		13.192 m			13.978 m	
Compost-Sand						
Grab #1	164	37	78	399	13.0	97
Grab #2	163	25	85	175	13.0	93
Grab #3	160	14	91	200	31.9	84
Grab #4	188	12	94	179	no sample	N/A
Grab #5	207	68	67	240	no sample	N/A
Grab #6	270	no sample	N/A	277	no sample	N/A
Enretech-Sand						
Grab #1	164	132	20	399	9.0	98
Grab #2	163	140	14	175	2.3	99
Grab #3	160	133	17	200	5.9	97
Grab #4	188	139	26	179	7.4	96
Grab #5	207	117	43	240	4.5	98
Grab #6	270	131	52	277	2.5	99
Sand						
Grab #1	164	136	17	399	2.2	99
Grab #2	163	137	16	175	1.8	99
Grab #3	160	148	8	200	9.2	95
Grab #4	188	143	24	179	2.7	98
Grab #5	207	123	41	240	3.4	99
Grab #6	270	147	46	277	0.0	100



ZINC: Bench-Scale Testing

CONTRAST TABLE EFFLUENT QUALITY ZINC

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	62.84	6	5.82
2	1	-1	-1	10.62	6	4.07
3	-1	1	-1	92.24	6	6.57
4	1	1	1	22.24	6	14.96
Effect	-61.11	20.51	-8.90	46.98		8.91

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	68.65	6	7.01
2	1	-1	-1	1.94	6	0.90
3	-1	1	-1	117.83	6	2.53
4	1	1	1	12.96	6	2.25
Effect	-86	30	-19	50.35		3.92

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	16.97	6	4.61
2	1	-1	-1	35.03	6	4.71
3	-1	1	-1	131.23	6	6.67
4	1	1	1	3.05	6	1.46
Effect	-55	41	-73	46.57		4.74

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	9.00	6	2.04
2	1	-1	-1	17.64	6	1.49
3	-1	1	-1	31.15	5	10.29
4	1	1	1	19.29	3	6.32
Effect	-2	12	-10	19.27		5.64

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	103.02	6	4.86
2	1	-1	-1	35.86	6	2.10
3	-1	1	-1	132.07	6	3.39
4	1	1	1	5.26	6	1.09
Effect	-97	-1	-30	69.05		3.19

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	97.93	6	3.96
2	1	-1	-1	43.24	6	5.40
3	-1	1	-1	138.83	6	3.76
4	1	1	1	3.21	6	1.28
Effect	-95	0	-40	70.80		3.89

CONTRAST TABLE REMOVAL EFFICIENCY ZINC

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	49	6	3.71
2	1	-1	-1	92	6	2.65
3	-1	1	-1	50	6	5.44
4	1	1	1	88	6	8.56
Effect	40.50	-1.50	-2.50	69.92		5.56

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	48	6	5.14
2	1	-1	-1	98	6	0.80
3	-1	1	-1	37	6	5.17
4	1	1	1	94	6	1.05
Effect	54.08	-7.75	3.75	69.29		3.71

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	87	6	3.50
2	1	-1	-1	72	6	4.01
3	-1	1	-1	30	6	4.13
4	1	1	1	99	6	0.76
Effect	26.50	-15.00	42.00	71.92		3.39

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	93	6	1.58
2	1	-1	-1	86	6	1.23
3	-1	1	-1	83	5	4.85
4	1	1	1	91	3	3.84
Effect	0.42	-2.25	7.92	88.29		2.91

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	22	6	3.84
2	1	-1	-1	71	6	2.01
3	-1	1	-1	29	6	6.28
4	1	1	1	98	6	0.48
Effect	59.25	17.08	9.92	54.71		3.82

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	26	6	2.79
2	1	-1	-1	66	6	2.68
3	-1	1	-1	25	6	6.14
4	1	1	1	98	6	0.71
Effect	56.58	16.08	16.42	53.79		3.65

COPPER (µg/L)

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Activated Carbon-Sand									
Grab #1	13.94	9.53	32	24.55	3.50	86	18.50	2.58	86
Grab #2	11.84	6.57	45	24.81	3.06	88	17.54	2.68	85
Grab #3	14.33	13.54	6	24.35	4.13	83	17.99	3.86	79
Grab #4	13.74	15.33	-12	26.68	3.15	88	21.51	4.12	81
Grab #5	15.28	15.98	-5	27.54	3.89	86	22.70	4.94	78
Grab #6	13.41	13.16	2	28.55	3.91	86	18.29	8.29	55
Peat-Sand									
Grab #1	13.94	31.79	-128	24.55	5.57	77	18.50	16.21	12
Grab #2	11.84	28.80	-143	24.81	6.49	74	17.54	11.50	34
Grab #3	14.33	16.12	-12	24.35	7.72	68	17.99	8.27	54
Grab #4	13.74	17.71	-29	26.68	2.85	89	21.51	12.89	40
Grab #5	15.28	no sample	N/A	27.54	3.10	89	22.70	10.68	53
Grab #6	13.41	no sample	N/A	28.55	4.71	84	18.29	11.94	35
Zeolite-Sand									
Grab #1	13.94	22.95	-65	24.55	16.01	35	18.50	18.86	-2
Grab #2	11.84	13.23	-12	24.81	8.44	66	17.54	19.05	-9
Grab #3	14.33	11.12	22	24.35	10.98	55	17.99	16.37	9
Grab #4	13.74	12.03	12	26.68	6.92	74	21.51	15.01	30
Grab #5	15.28	13.24	13	27.54	12.69	54	22.70	14.58	36
Grab #6	13.41	10.21	24	28.55	3.28	89	18.29	13.00	29

FILTRATION MEDIA EVALUATION: Bench-Scale Testing
Summer 1995

COPPER (µg/L) (Continued)

SAMPLE GROUP NAME	Neutral pH, High Ionic Strength			Low pH, Low Ionic Strength			High pH, Low Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	1.964 m			2.302 m			1.964 m		
Grab #2	3.649 m			4.098 m			3.761 m		
Grab #3	5.333 m			5.782 m			5.614 m		
Grab #4	7.017 m			7.747 m			7.578 m		
Grab #5	8.982 m			9.543 m			9.262 m		
Grab #6	11.789 m			11.676 m			11.227 m		
Compost-Sand									
Grab #1	13.94	13.04	6	24.55	2.02	92	18.50	15.38	17
Grab #2	11.84	10.80	9	24.81	3.12	87	17.54	12.53	29
Grab #3	14.33	10.24	29	24.35	1.30	95	17.99	11.59	36
Grab #4	13.74	10.18	26	26.68	0.90	97	21.51	11.39	47
Grab #5	15.28	14.40	6	27.54	2.56	91	22.70	12.81	44
Grab #6	13.41	8.78	35	28.55	6.42	78	18.29	10.41	43
Enretech-Sand									
Grab #1	13.94	5.44	61	24.55	7.03	71	18.50	11.05	40
Grab #2	11.84	5.78	51	24.81	6.15	75	17.54	12.89	27
Grab #3	14.33	7.53	47	24.35	10.59	57	17.99	14.16	21
Grab #4	13.74	6.81	50	26.68	10.12	62	21.51	13.59	37
Grab #5	15.28	5.15	66	27.54	6.79	75	22.70	13.12	42
Grab #6	13.41	4.75	65	28.55	13.51	53	18.29	29.51	-61
Sand									
Grab #1	13.94	5.90	58	24.55	11.17	55	18.50	12.23	34
Grab #2	11.84	5.75	51	24.81	10.11	59	17.54	8.45	52
Grab #3	14.33	3.48	76	24.35	12.34	49	17.99	9.14	49
Grab #4	13.74	3.60	74	26.68	6.77	75	21.51	13.11	39
Grab #5	15.28	5.57	64	27.54	12.32	55	22.70	10.39	54
Grab #6	13.41	3.36	75	28.55	12.81	55	18.29	8.30	55

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

COPPER (µg/L) (Continued)

Summer 1995

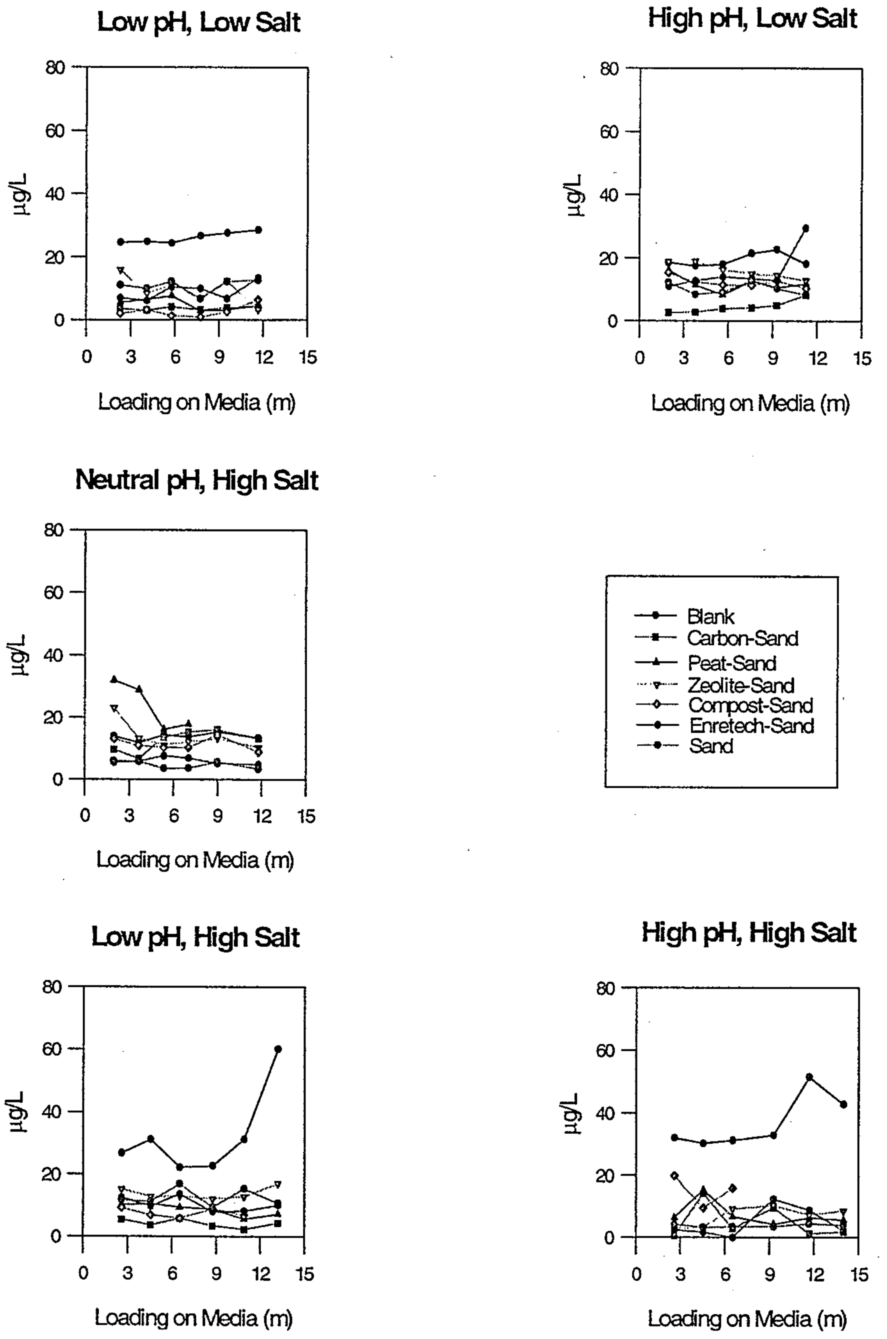
SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Activated Carbon-Sand						
Grab #1	26.63	5.46	80	31.85	0.44	99
Grab #2	31.00	3.60	88	30.09	14.23	53
Grab #3	22.16	5.78	74	31.03	2.67	91
Grab #4	22.64	3.40	85	32.71	9.49	71
Grab #5	31.17	2.22	93	51.39	1.14	98
Grab #6	60.04	4.27	93	42.74	1.63	96
Peat-Sand						
Grab #1	26.63	10.25	62	31.85	6.27	80
Grab #2	31.00	10.56	66	30.09	15.33	49
Grab #3	22.16	9.47	57	31.03	6.67	79
Grab #4	22.64	8.71	62	32.71	4.11	87
Grab #5	31.17	5.67	82	51.39	6.32	88
Grab #6	60.04	7.25	88	42.74	5.46	87
Zeolite-Sand						
Grab #1	26.63	15.32	42	31.85	2.70	92
Grab #2	31.00	12.96	58	30.09	3.24	89
Grab #3	22.16	13.05	41	31.03	9.19	70
Grab #4	22.64	12.14	46	32.71	10.31	68
Grab #5	31.17	12.96	58	51.39	7.15	86
Grab #6	60.04	17.13	71	42.74	8.57	80

FILTRATION MEDIA EVALUATION: Bench-Scale Testing

COPPER (µg/L) (Continued)

Summer 1995

SAMPLE GROUP NAME	Low pH, High Ionic Strength			High pH, High Ionic Strength		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Grab #1	2.582 m			2.582 m		
Grab #2	4.547 m			4.547 m		
Grab #3	6.512 m			6.512 m		
Grab #4	8.757 m			9.262 m		
Grab #5	10.890 m			11.676 m		
Grab #6	13.192 m			13.978 m		
Compost-Sand						
Grab #1	26.63	9.31	65	31.85	19.81	38
Grab #2	31.00	6.89	78	30.09	9.51	68
Grab #3	22.16	5.92	73	31.03	15.89	49
Grab #4	22.64	8.86	61	32.71	no sample	N/A
Grab #5	31.17	6.87	78	51.39	no sample	N/A
Grab #6	60.04	no sample	N/A	42.74	no sample	N/A
Enretech-Sand						
Grab #1	26.63	12.60	53	31.85	2.39	93
Grab #2	31.00	9.81	68	30.09	1.53	95
Grab #3	22.16	13.81	38	31.03	0.00	100
Grab #4	22.64	8.05	64	32.71	12.33	62
Grab #5	31.17	8.25	74	51.39	8.85	83
Grab #6	60.04	10.21	83	42.74	2.03	95
Sand						
Grab #1	26.63	11.77	56	31.85	4.10	87
Grab #2	31.00	11.40	63	30.09	3.15	90
Grab #3	22.16	16.93	24	31.03	3.35	89
Grab #4	22.64	9.54	58	32.71	3.38	90
Grab #5	31.17	15.45	50	51.39	4.32	92
Grab #6	60.04	10.74	82	42.74	3.89	91



COPPER: Bench-Scale Testing

CONTRAST TABLE EFFLUENT QUALITY COPPER

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	3.61	6	0.18
2	1	-1	-1	4.41	6	0.86
3	-1	1	-1	4.12	6	0.55
4	1	1	1	4.93	6	2.29
Effect	0.81	0.52	0.00	4.27		1.26

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	5.07	6	0.78
2	1	-1	-1	11.92	6	1.07
3	-1	1	-1	8.65	6	0.77
4	1	1	1	7.36	6	1.64
Effect	2.78	-0.49	-4.07	8.25		1.12

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	9.72	6	1.83
2	1	-1	-1	16.14	6	0.99
3	-1	1	-1	13.93	6	0.78
4	1	1	1	6.86	6	1.30
Effect	-0.32	-2.54	-6.75	11.66		1.29

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	2.72	6	0.81
2	1	-1	-1	12.35	6	0.70
3	-1	1	-1	7.57	5	0.65
4	1	1	1	15.07	3	3.00
Effect	8.57	3.79	-1.07	9.43		1.10

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	9.03	6	1.17
2	1	-1	-1	15.72	6	2.79
3	-1	1	-1	10.45	6	0.95
4	1	1	1	4.52	6	2.00
Effect	0.38	-4.89	-6.31	9.93		1.87

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	10.92	6	0.92
2	1	-1	-1	10.27	6	0.85
3	-1	1	-1	12.64	6	1.18
4	1	1	1	3.70	6	0.19
Effect	-4.79	-2.43	-4.15	9.38		0.87

CONTRAST TABLE REMOVAL EFFICIENCY COPPER

CARBON-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	86	6	0.75
2	1	-1	-1	77	6	4.65
3	-1	1	-1	86	6	3.06
4	1	1	1	85	6	7.62
Effect	-4.83	3.33	4.00	83.42		4.73

PEAT-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	80	6	3.50
2	1	-1	-1	38	6	6.29
3	-1	1	-1	70	6	5.10
4	1	1	1	78	6	6.08
Effect	-16.67	14.83	25.50	66.50		5.35

ZEOLITE-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	62	6	7.60
2	1	-1	-1	16	6	7.66
3	-1	1	-1	53	6	4.79
4	1	1	1	81	6	4.09
Effect	-9.25	27.92	37.42	52.79		6.25

COMPOST-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	90	6	2.78
2	1	-1	-1	36	6	4.63
3	-1	1	-1	71	5	3.45
4	1	1	1	52	3	8.76
Effect	-36.67	-1.67	17.33	62.17		4.44

ENRETECH-SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	66	6	3.88
2	1	-1	-1	18	6	16.07
3	-1	1	-1	63	6	6.51
4	1	1	1	88	6	5.68
Effect	-11.50	34.00	36.33	58.58		9.33

SAND

Run #	pH	Salt	(pH)(Salt)	Result	# Obs.	S.E.
1	-1	-1	1	58	6	3.64
2	1	-1	-1	47	6	3.53
3	-1	1	-1	56	6	7.72
4	1	1	1	90	6	0.70
Effect	11.75	20.08	22.58	62.63		4.63

Appendix C:
Physical Parameters

Toxicity
Turbidity
Conductivity
Color
pH

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

TOXICITY

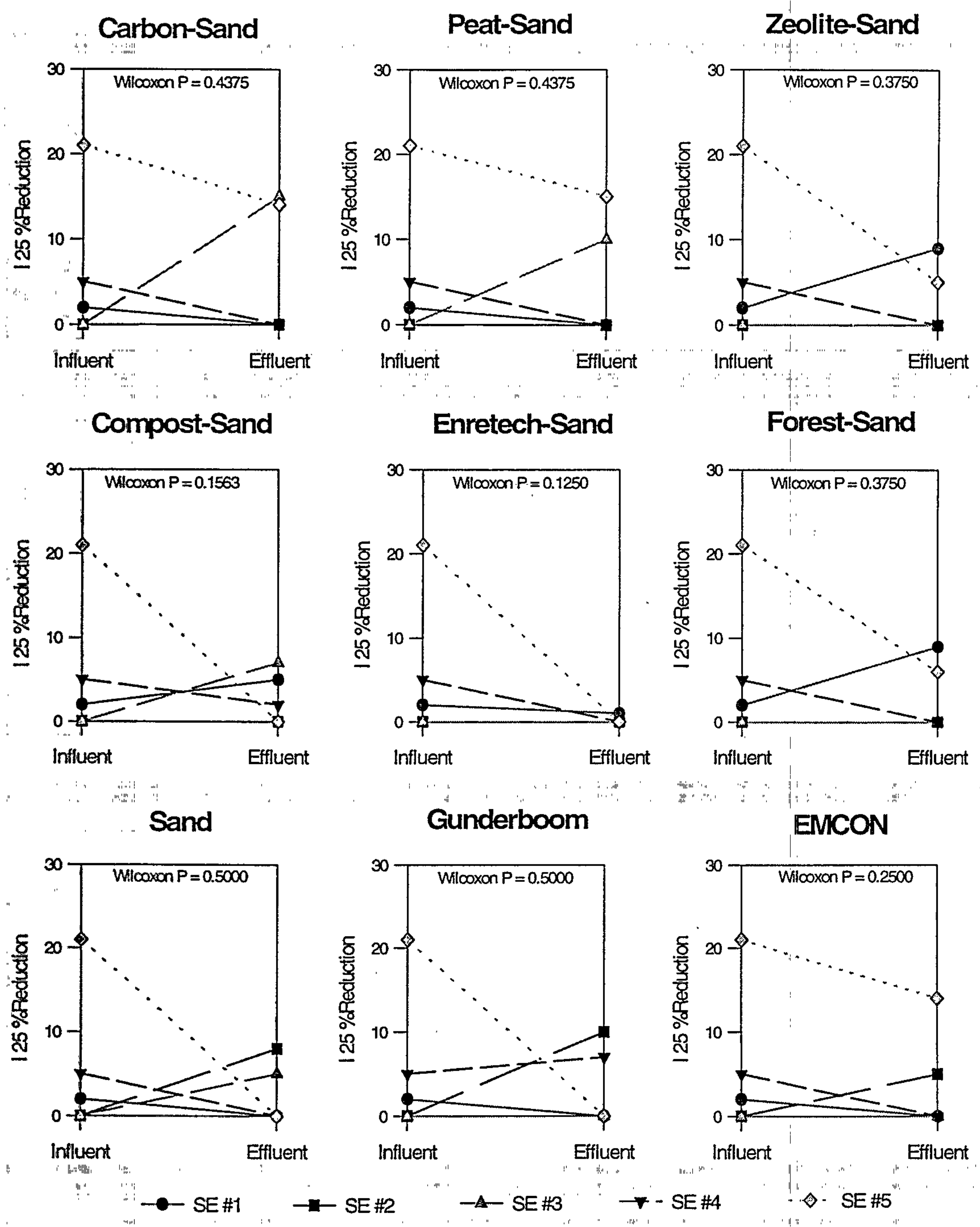
SAMPLE GROUP NAME	Unfiltered Fraction (I25 %Reduction)			Filtered Fraction (I25 %Reduction)			Particulate Fraction (I25 %Reduction)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
8.5 m	2	<0	100	<0	<0	N/A	11	31	-182
13.1 m	<0	<0	N/A	4	<0	100	<0	<0	N/A
16.4 m	<0	15	N/A	16	<0	100	<0	21	N/A
20.6 m	5	<0	100	11	<0	100	<0	2	N/A
25.0 m	21	14	33	22	15	32	<0	<0	N/A
Peat-Sand									
8.5 m	2	<0	100	<0	<0	N/A	11	<0	100
13.1 m	<0	<0	N/A	4	<0	100	<0	<0	N/A
16.4 m	<0	10	N/A	16	6	63	<0	4	N/A
20.6 m	5	<0	100	11	4	64	<0	<0	N/A
25.0 m	21	15	29	22	17	23	<0	<0	N/A
Zeolite-Sand									
8.5 m	2	9	-350	<0	<0	N/A	11	15	-36
13.1 m	<0	<0	N/A	4	<0	100	<0	<0	N/A
16.4 m	<0	<0	N/A	16	<0	100	<0	<0	N/A
20.6 m	5	<0	100	11	<0	100	<0	<0	N/A
25.0 m	21	5	76	22	<0	100	<0	10	N/A
Compost-Sand									
8.5 m	2	5	-150	<0	8	N/A	11	<0	100
13.1 m	<0	0	N/A	4	20	-400	<0	<0	N/A
16.4 m	<0	7	N/A	16	<0	100	<0	12	N/A
20.6 m	5	2	60	11	<0	100	<0	13	N/A
25.0 m	21	<0	100	22	14	36	<0	<0	N/A
Enretech-Sand									
8.5 m	2	1	50	<0	13	N/A	11	<0	100
13.1 m	<0	0	N/A	4	1	75	<0	<0	N/A
16.4 m	<0	<0	N/A	16	<0	100	<0	5	N/A
20.6 m	5	<0	100	11	<0	100	<0	<0	N/A
25.0 m	21	<0	100	22	3	86	<0	<0	N/A

FILTRATION MEDIA EVALUATION: PreSettled Influent

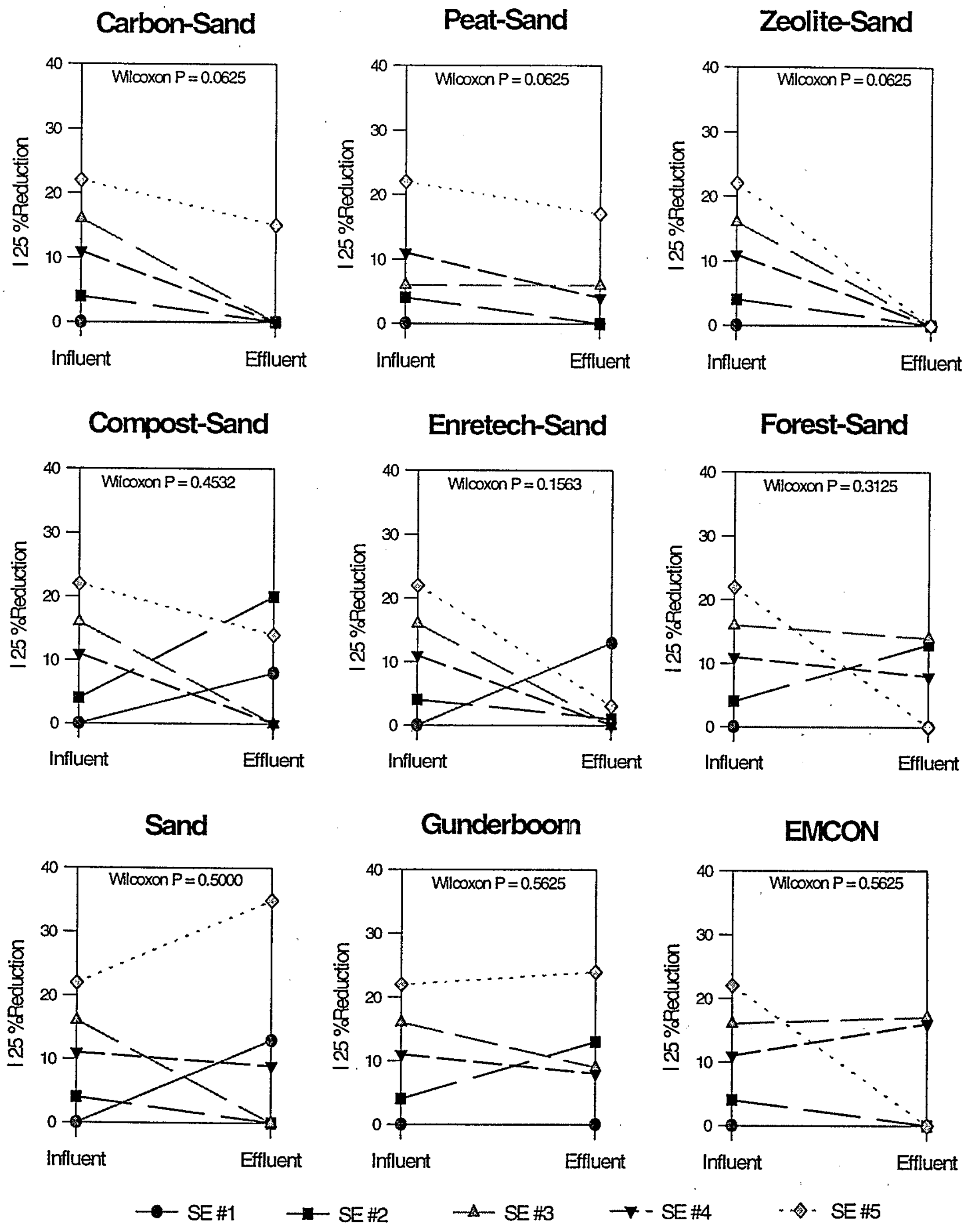
Fall 1995

TOXICITY (Continued)

SAMPLE GROUP NAME	Unfiltered Fraction (I25 %Reduction)			Filtered Fraction (I25 %Reduction)			Particulate Fraction (I25 %Reduction)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand									
8.5 m	2	9	-350	<0	<0	N/A	11	10	9
13.1 m	<0	<0	N/A	4	13	-225	<0	<0	N/A
16.4 m	<0	<0	N/A	16	14	13	<0	<0	N/A
20.6 m	5	<0	100	11	8	27	<0	<0	N/A
25.0 m	21	6	71	22	<0	100	<0	9	N/A
Sand									
8.5 m	2	<0	100	<0	13	N/A	11	<0	100
13.1 m	<0	8	N/A	4	<0	100	<0	11	N/A
16.4 m	<0	5	N/A	16	<0	100	<0	10	N/A
20.6 m	5	<0	100	11	9	18	<0	<0	N/A
25.0 m	21	<0	100	22	35	-59	<0	<0	N/A
Gunderboom Fabric									
8.5 m	2	<0	100	<0	<0	N/A	11	<0	100
13.1 m	<0	10	N/A	4	13	-225	<0	<0	N/A
16.4 m	<0	<0	N/A	16	9	44	<0	<0	N/A
20.6 m	5	7	-40	11	8	27	<0	<0	N/A
25.0 m	21	<0	100	22	24	-9	<0	<0	N/A
EMCON Fabric									
8.5 m	2	<0	100	<0	<0	N/A	11	1	91
13.1 m	<0	5	N/A	4	<0	100	<0	<0	N/A
16.4 m	<0	<0	N/A	16	17	-6	<0	<0	N/A
20.6 m	5	<0	100	11	16	-45	<0	<0	N/A
25.0 m	21	14	33	22	<0	100	<0	22	N/A



TOXICITY: PreSettled Influent
Unfiltered Fraction



TOXICITY: PreSettled Influent
Filtered Fraction

TOXICITY

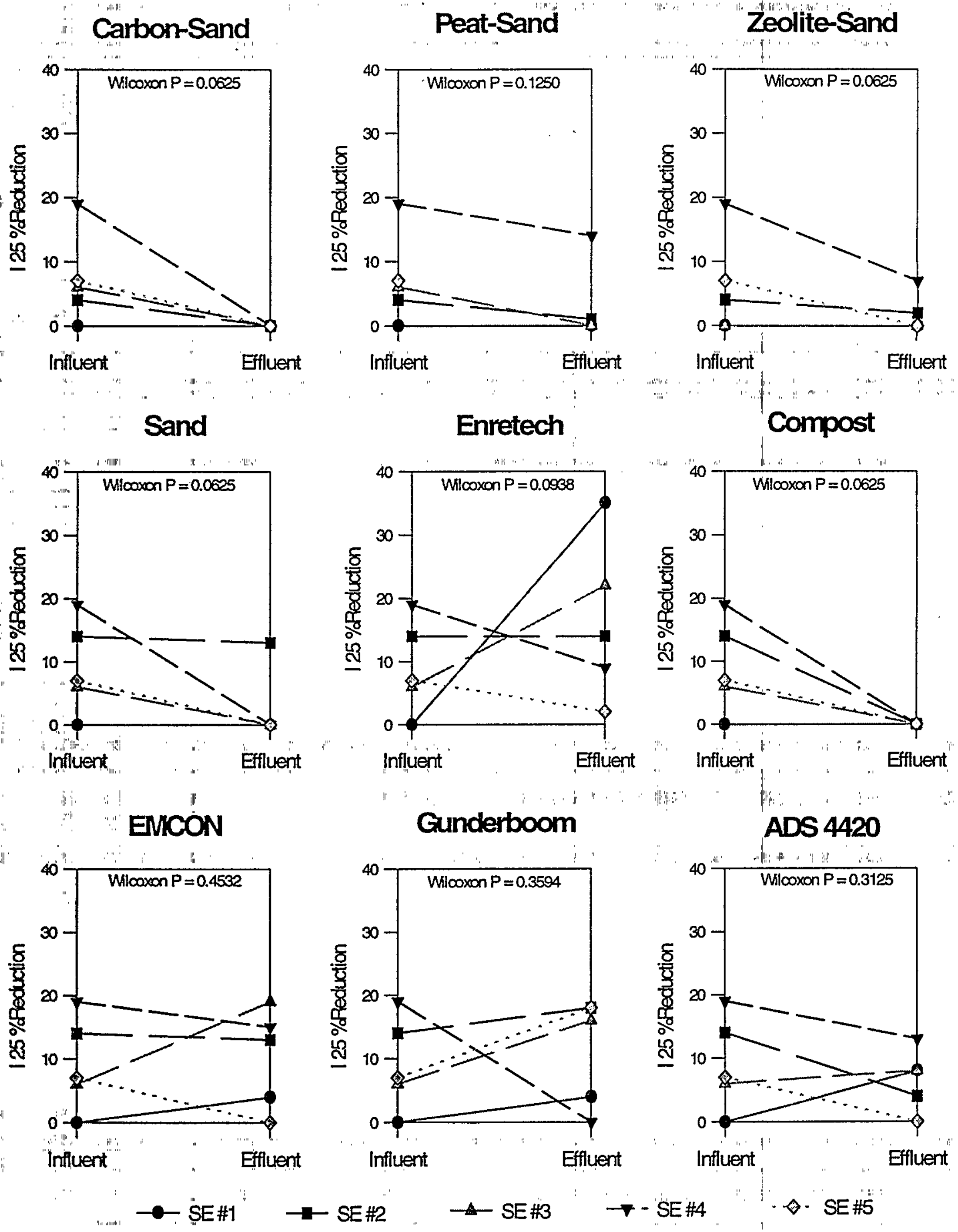
FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Unfiltered Fraction (I 25 % Reduction)			Filtered Fraction (I 25 % Reduction)			Particulate Fraction (I 25 % Reduction)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
1.1 m	0	0	N/A	12	0	100	0	0	N/A
2.2 m	14	0	100	17	0	100	0	0	N/A
3.3 m	6	0	100	26	0	100	0	0	N/A
4.4 m	19	0	100	23	6	74	0	0	N/A
5.5 m	7	0	100	15	0	100	0	0	N/A
Peat-Sand									
1.1 m	0	0	N/A	12	11	8	0	0	N/A
2.2 m	14	1	93	17	16	6	0	0	N/A
3.3 m	6	0	100	26	0	100	0	0	N/A
4.4 m	19	14	26	23	0	100	0	14	N/A
5.5 m	7	broken	100	15	1	93	0	0	N/A
Zeolite-Sand									
1.1 m	0	0	N/A	12	6	50	0	0	N/A
2.2 m	14	2	86	17	16	6	0	0	N/A
3.3 m	6	0	100	26	0	100	0	0	N/A
4.4 m	19	7	63	23	18	22	0	0	N/A
5.5 m	7	0	100	15	8	47	0	0	N/A
Sand									
1.1 m	0	0	N/A	12	18	-50	0	0	N/A
2.2 m	14	13	7	17	25	-47	0	0	N/A
3.3 m	6	0	100	26	0	100	0	0	N/A
4.4 m	19	0	100	23	4	83	0	0	N/A
5.5 m	7	0	100	15	3	80	0	0	N/A
Enretech									
1.1 m	0	35	N/A	12	46	-283	0	0	N/A
2.2 m	14	14	0	17	17	0	0	0	N/A
3.3 m	6	22	-267	26	22	15	0	0	N/A
4.4 m	19	9	53	23	10	57	0	0	N/A
5.5 m	7	2	71	15	9	40	0	0	N/A

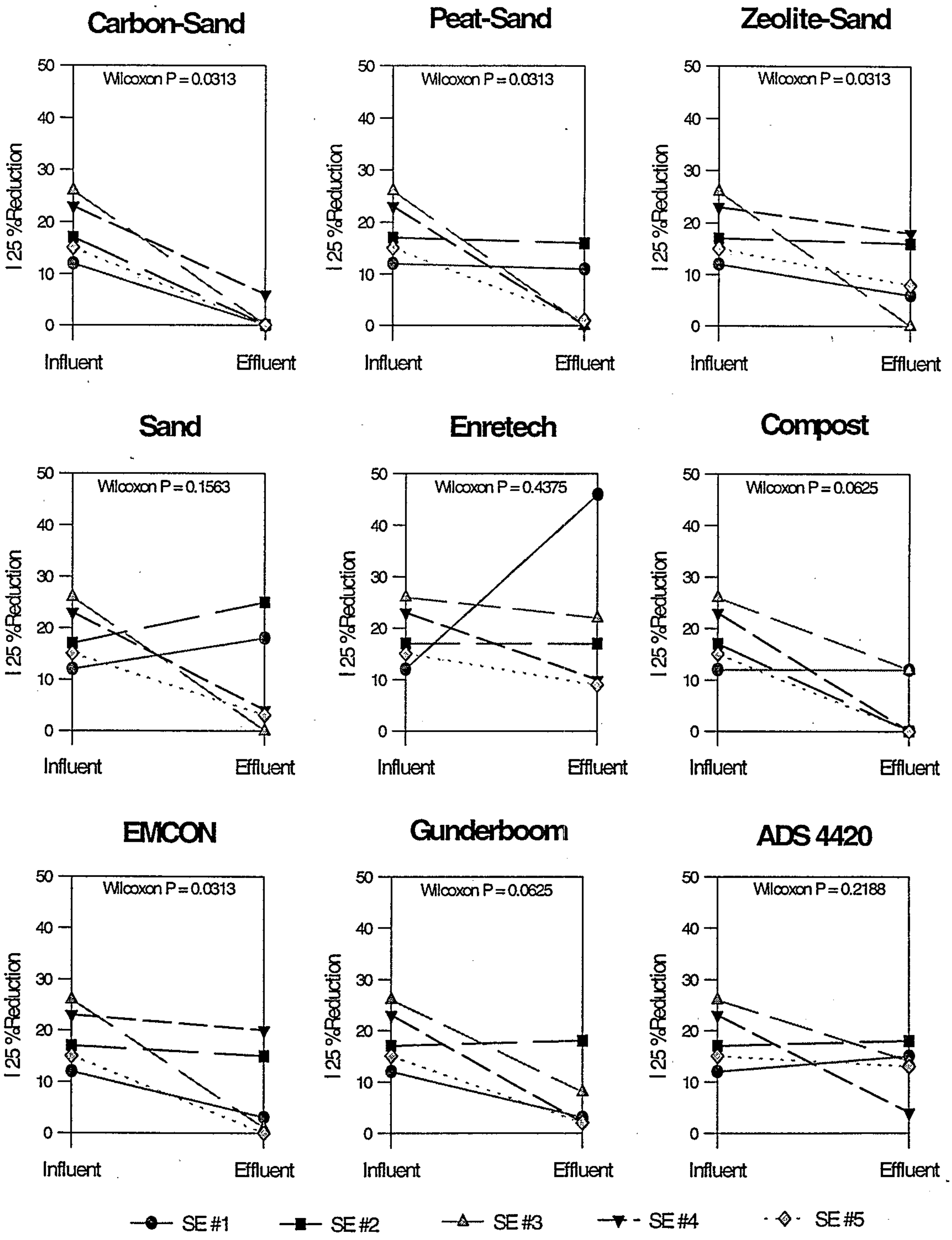
TOXICITY (Continued)

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Unfiltered Fraction (I 25 % Reduction)			Filtered Fraction (I 25 % Reduction)			Particulate Fraction (I 25 % Reduction)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost									
1.1 m	0	0	N/A	12	12	0	0	0	N/A
2.2 m	14	0	100	17	0	100	0	0	N/A
3.3 m	6	0	100	26	12	54	0	0	N/A
4.4 m	19	0	100	23	0	100	0	0	N/A
5.5 m	7	0	100	15	0	100	0	0	N/A
EMCON Fabric									
1.1 m	0	4	N/A	12	3	75	0	1	N/A
2.2 m	14	13	7	17	15	12	0	0	N/A
3.3 m	6	19	-217	26	1	96	0	18	N/A
4.4 m	19	15	21	23	20	13	0	0	N/A
5.5 m	7	0	100	15	0	100	0	0	N/A
Gunderboom Fabric									
1.1 m	0	4	N/A	12	3	75	0	0	N/A
2.2 m	14	18	-29	17	18	-6	0	0	N/A
3.3 m	6	16	-167	26	8	69	0	8	N/A
4.4 m	7	0	100	15	2	87	0	0	N/A
5.5 m	7	18	-157	15	2	87	0	16	N/A
ADS 4420 Fabric									
1.1 m	0	8	N/A	12	15	-25	0	0	N/A
2.2 m	14	4	71	17	18	-6	0	0	N/A
3.3 m	6	8	-33	26	14	46	0	0	N/A
4.4 m	19	13	32	23	4	83	0	0	N/A
5.5 m	7	0	100	15	13	13	0	0	N/A



TOXICITY: Unpretreated Influent
Unfiltered Fraction



TOXICITY: Unpretreated Influent
Filtered Fraction

FILTRATION MEDIA EVALUATION: PreSettled Influent

Fall 1995

TURBIDITY

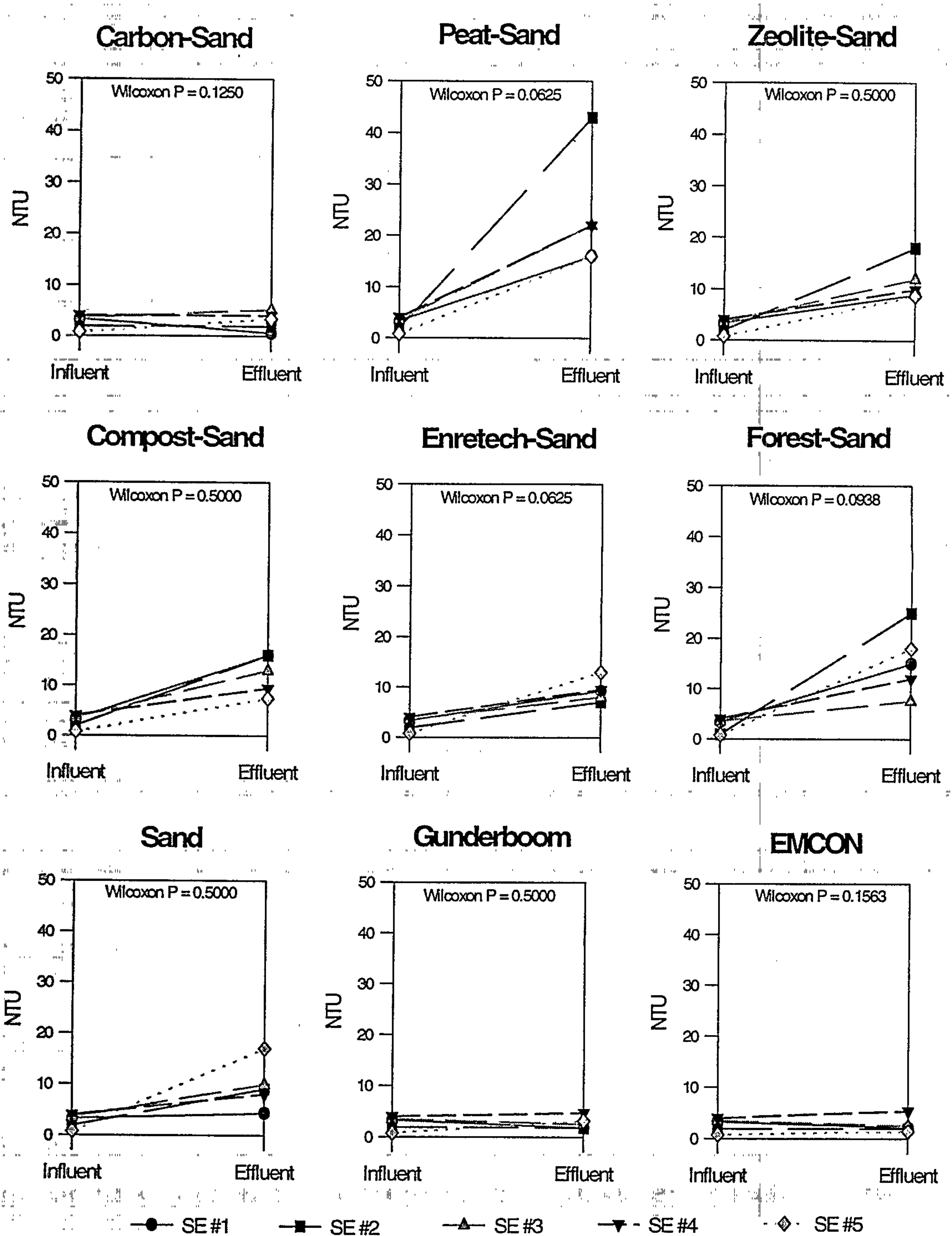
SAMPLE GROUP NAME	Unfiltered Fraction (NTU)			Filtered Fraction (NTU)			Particulate Fraction (NTU)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
8.5 m	3.3	0.56	83	1.0	0.56	44	2.3	0	100
13.1 m	1.9	1.9	0	1.1	1.3	-18	0.8	0.6	25
16.4 m	3.5	5.1	-46	1.2	2.5	-108	2.3	2.6	-13
20.6 m	4.0	4.0	0	3.0	1.4	53	1	2.6	-160
25.0 m	0.74	3.3	-346	0.27	1.0	-270	0.47	2.3	-389
Peat-Sand									
8.5 m	3.3	16	-385	1.0	2.7	-170	2.3	13.3	-478
13.1 m	1.9	43	-2163	1.1	2.2	-100	0.8	40.8	-5000
16.4 m	3.5	22	-529	1.2	2.0	-67	2.3	20	-770
20.6 m	4.0	22	-450	3.0	2.2	27	1	19.8	-1880
25.0 m	0.74	16	-2062	0.27	5.8	-2048	0.47	10.2	-2070
Zeolite-Sand									
8.5 m	3.3	9.0	-173	1.0	1.4	-40	2.3	7.6	-230
13.1 m	1.9	18	-847	1.1	1.9	-73	0.8	16.1	-1913
16.4 m	3.5	12	-243	1.2	1.2	0	2.3	10.8	-370
20.6 m	4.0	10	-150	3.0	1.1	63	1	8.9	-790
25.0 m	0.74	8.7	-1076	0.27	1.8	-567	0.47	6.9	-1368
Compost-Sand									
8.5 m	3.3	16	-385	1.0	4.0	-300	2.3	12	-422
13.1 m	1.9	16	-742	1.1	2.5	-127	0.8	13.5	-1588
16.4 m	3.5	13	-271	1.2	2.3	-92	2.3	10.7	-365
20.6 m	4.0	9.4	-135	3.0	1.9	37	1	7.5	-650
25.0 m	0.74	7.4	-900	0.27	3.9	-1344	0.47	3.7	-687
Enretech-Sand									
8.5 m	3.3	9.2	-179	1.0	1.5	-50	2.3	7.7	-235
13.1 m	1.9	17	-795	1.1	2.4	-118	0.8	14.6	-1725
16.4 m	3.5	8.0	-129	1.2	2.0	-67	2.3	6	-161
20.6 m	4.0	9.5	-138	3.0	2.0	33	1	7.5	-650
25.0 m	0.74	13	-1657	0.27	2.7	-900	0.47	10.3	-2091

FILTRATION MEDIA EVALUATION: PreSettled Influent

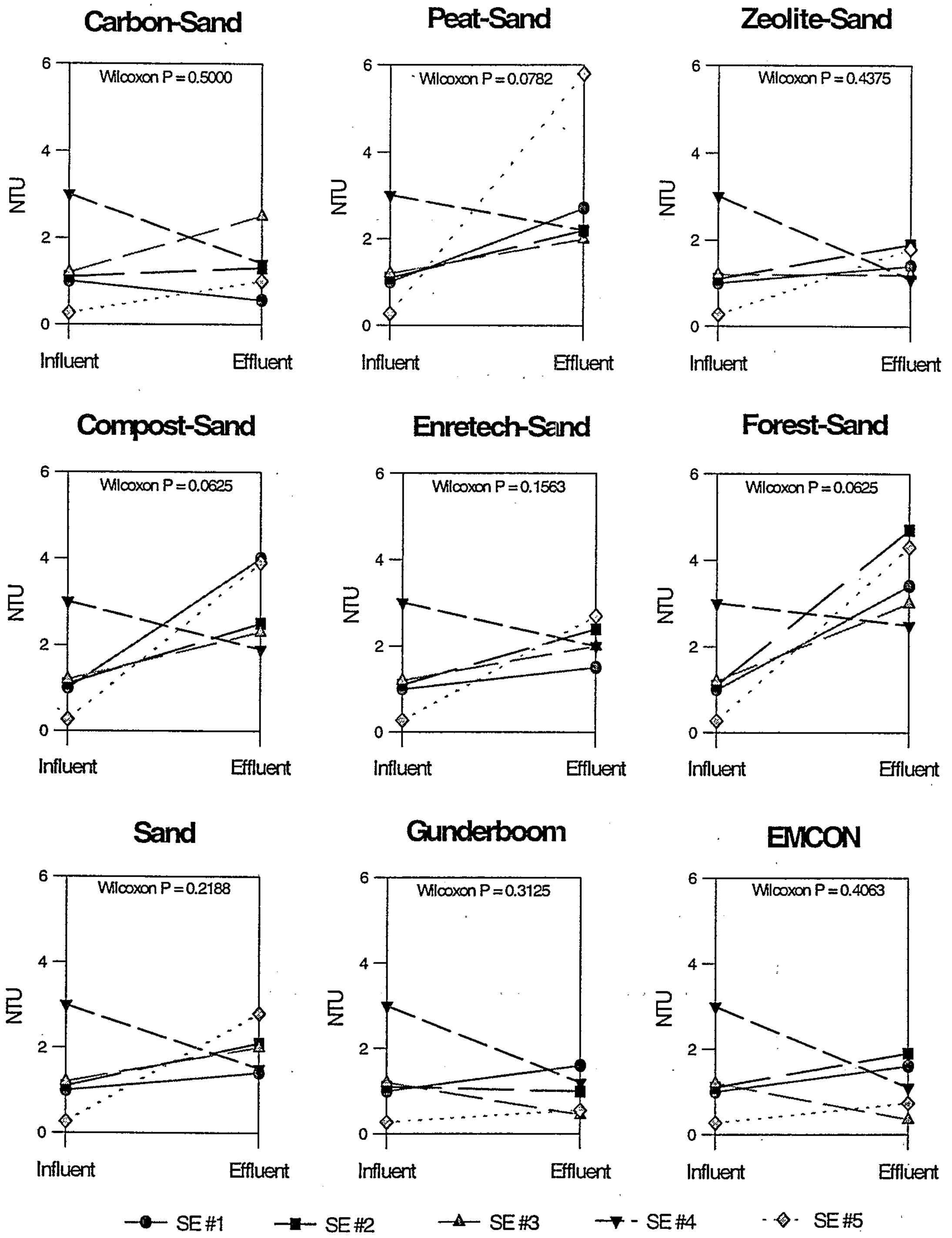
Fall 1995

TURBIDITY (Continued)

SAMPLE GROUP NAME	Unfiltered Fraction (NTU)			Filtered Fraction (NTU)			Particulate Fraction (NTU)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand									
8.5 m	3.3	15	-355	1.0	3.4	-240	2.3	11.6	-404
13.1 m	1.9	25	-1216	1.1	4.7	-327	0.8	20.3	-2438
16.4 m	3.5	7.5	-114	1.2	3.0	-150	2.3	4.5	-96
20.6 m	4.0	12	-200	3.0	2.5	17	1	9.5	-850
25.0 m	0.74	18	-2332	0.27	4.3	-1493	0.47	13.7	-2815
Sand									
8.5 m	3.3	4.3	-30	1.0	1.4	-40	2.3	2.9	-26
13.1 m	1.9	19	-900	1.1	2.1	-91	0.8	16.9	-2013
16.4 m	3.5	9.9	-183	1.2	2.0	-67	2.3	7.9	-243
20.6 m	4.0	8.0	-100	3.0	1.5	50	1	6.5	-550
25.0 m	0.74	17	-2197	0.27	2.8	-937	0.47	14.2	-2921
Gunderboom Fabric									
8.5 m	3.3	1.8	45	1.0	1.6	-60	2.3	0.2	91
13.1 m	1.9	1.8	5	1.1	1.0	9	0.8	0.8	0
16.4 m	3.5	2.5	29	1.2	0.45	63	2.3	2.05	11
20.6 m	4.0	4.7	-18	3.0	1.2	60	1	3.5	-250
25.0 m	0.74	3.2	-332	0.27	0.56	-107	0.47	2.64	-462
EMCON Fabric									
8.5 m	3.3	2.1	36	1.0	1.6	-60	2.3	0.5	78
13.1 m	1.9	1.9	0	1.1	1.9	-73	0.8	0	100
16.4 m	3.5	2.5	29	1.2	0.35	71	2.3	2.15	7
20.6 m	4.0	5.4	-35	3.0	1.1	63	1	4.3	-330
25.0 m	0.74	1.4	-89	0.27	0.74	-174	0.47	0.66	-40



TURBIDITY: PreSettled Influent
Unfiltered Fraction



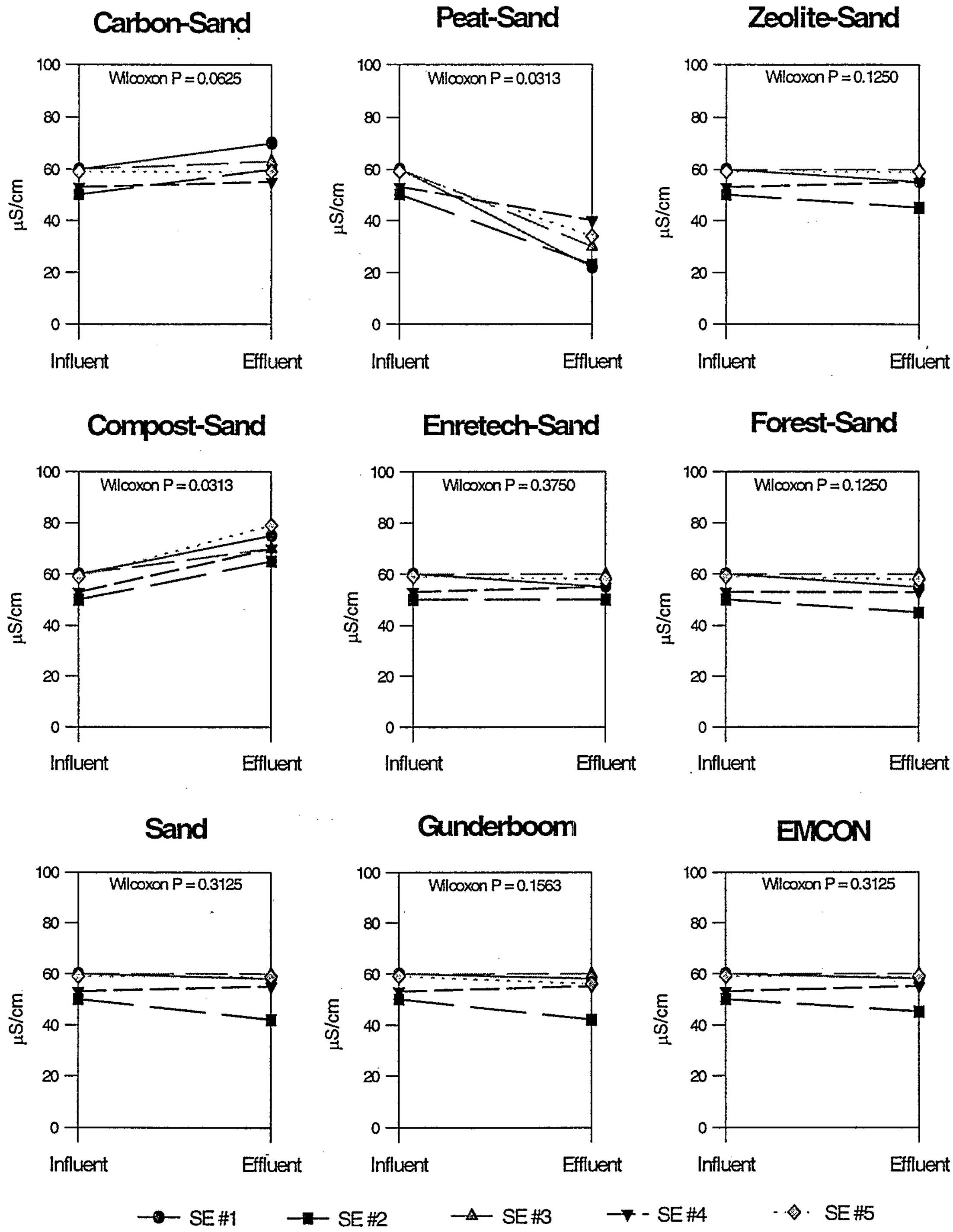
TURBIDITY: PreSettled Influent
Filtered Fraction

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

CONDUCTIVITY

SAMPLE GROUP NAME	µS/cm		
	Influent	Effluent	% Decrease
Activated Carbon-Sand			
8.5 m	60	70	-17
13.1 m	50	60	-20
16.4 m	60	63	-5
20.6 m	53	55	-4
25.0 m	59	59	0
Peat-Sand			
8.5 m	60	22	63
13.1 m	50	23	54
16.4 m	60	30	50
20.6 m	53	40	25
25.0 m	59	34	42
Zeolite-Sand			
8.5 m	60	55	8
13.1 m	50	45	10
16.4 m	60	60	0
20.6 m	53	55	-4
25.0 m	59	59	0
Compost-Sand			
8.5 m	60	75	-25
13.1 m	50	65	-30
16.4 m	60	70	-17
20.6 m	53	70	-32
25.0 m	59	79	-34
Enretech-Sand			
8.5 m	60	55	8
13.1 m	50	50	0
16.4 m	60	60	0
20.6 m	53	55	-4
25.0 m	59	58	2

SAMPLE GROUP NAME	µS/cm		
	Influent	Effluent	% Decrease
Forest Products-Sand			
8.5 m	60	55	8
13.1 m	50	45	10
16.4 m	60	60	0
20.6 m	53	53	0
25.0 m	59	58	2
Sand			
8.5 m	60	58	3
13.1 m	50	42	16
16.4 m	60	60	0
20.6 m	53	55	-4
25.0 m	59	59	0
Gunderboom Fabric			
8.5 m	60	58	3
13.1 m	50	42	16
16.4 m	60	60	0
20.6 m	53	55	-4
25.0 m	59	56	5
EMCON Fabric			
8.5 m	60	58	3
13.1 m	50	45	10
16.4 m	60	60	0
20.6 m	53	55	-4
25.0 m	59	59	0



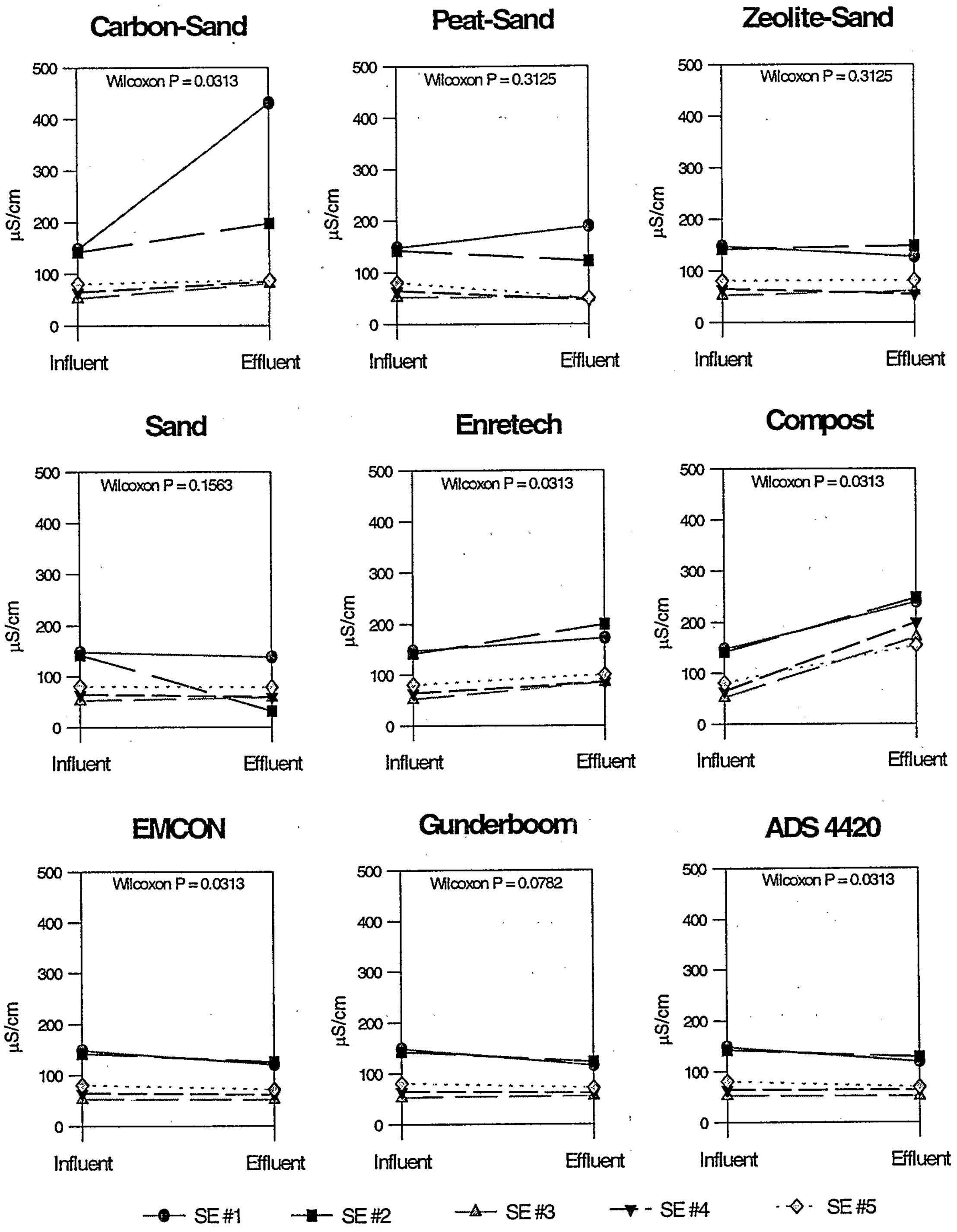
CONDUCTIVITY: PreSettled Influent

FILTRATION MEDIA EVALUATION: Unpreatreated Influent
Summer 1994

CONDUCTIVITY

SAMPLE GROUP NAME	µS/cm		
	Influent	Effluent	% Decrease
Activated Carbon-Sand			
1.1 m	148	431	-191
2.2 m	142	197	-39
3.3 m	53	81	-53
4.4 m	65	85	-31
5.5 m	81	88	-9
Peat-Sand			
1.1 m	148	189	-28
2.2 m	142	122	14
3.3 m	53	52	2
4.4 m	65	47	28
5.5 m	81	51	37
Zeolite-Sand			
1.1 m	148	127	14
2.2 m	142	149	-5
3.3 m	53	61	-15
4.4 m	53	55	-4
5.5 m	81	82	-1
Sand			
1.1 m	148	138	7
2.2 m	142	132	7
3.3 m	53	59	-11
4.4 m	65	60	8
5.5 m	81	79	2
Enretech			
1.1 m	148	172	-16
2.2 m	142	199	-40
3.3 m	53	85	-60
4.4 m	65	85	-31
5.5 m	81	100	-23

SAMPLE GROUP NAME	µS/cm		
	Influent	Effluent	% Decrease
Compost			
1.1 m	148	240	-62
2.2 m	142	248	-75
3.3 m	53	171	-223
4.4 m	65	200	-208
5.5 m	81	155	-91
EMCON Fabric			
1.1 m	148	120	19
2.2 m	142	125	12
3.3 m	53	52	2
4.4 m	65	62	5
5.5 m	81	69	15
Gunderboom Fabric			
1.1 m	148	115	22
2.2 m	142	122	14
3.3 m	53	56	-6
4.4 m	65	62	5
5.5 m	81	72	11
ADS 4420 Fabric			
1.1 m	148	119	20
2.2 m	142	128	10
3.3 m	53	52	2
4.4 m	65	64	2
5.5 m	81	70	14



CONDUCTIVITY: Unpretreated Influent

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

COLOR

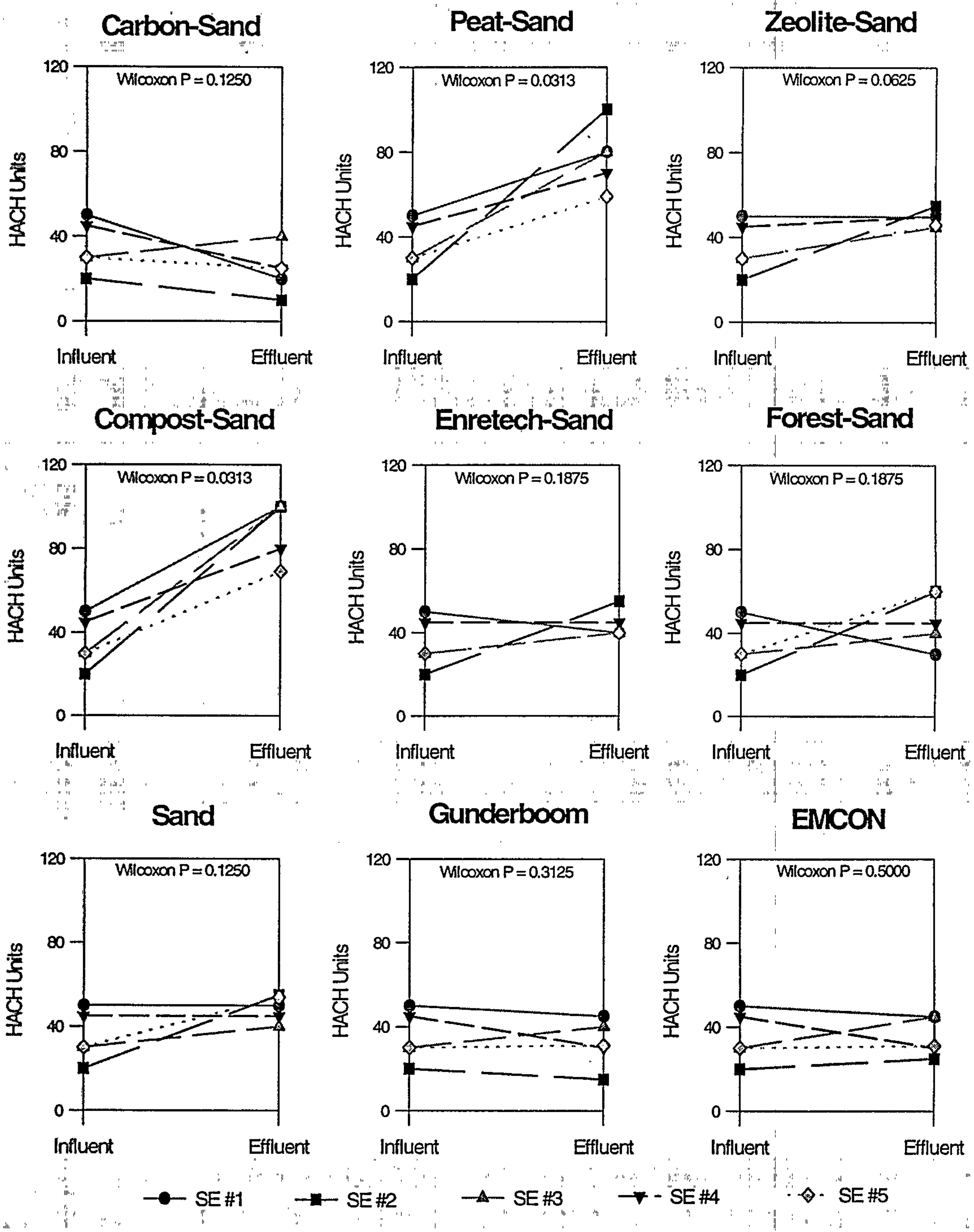
SAMPLE GROUP NAME	Unfiltered Fraction (Apparent HACH Units)			Filtered Fraction (Apparent HACH Units)			Particulate Fraction (Apparent HACH Units)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
8.5 m	50	20	60	45	40	11	5	-20	500
13.1 m	20	10	50	13	10	23	7	0	100
16.4 m	30	40	-33	25	20	20	5	20	-300
20.6 m	45	25	44	45	20	56	0	5	N/A
25.0 m	30	25	17	28	23	18	2	2	0
Peat-Sand									
8.5 m	50	80	-60	45	40	11	5	40	-700
13.1 m	20	100	-400	13	40	-208	7	60	-757
16.4 m	30	80	-167	25	45	-80	5	35	-600
20.6 m	45	70	-56	45	45	0	0	25	N/A
25.0 m	30	59	-97	28	44	-57	2	15	-650
Zeolite-Sand									
8.5 m	50	50	0	45	40	11	5	10	-100
13.1 m	20	55	-175	13	20	-54	7	35	-400
16.4 m	30	45	-50	25	40	-60	5	5	0
20.6 m	45	50	-11	45	40	11	0	10	N/A
25.0 m	30	46	-53	28	31	-11	2	15	-650
Compost-Sand									
8.5 m	50	100	-100	45	100	-122	5	0	100
13.1 m	20	100	-400	13	85	-554	7	15	-114
16.4 m	30	100	-233	25	80	-220	5	20	-300
20.6 m	45	80	-78	45	70	-56	0	10	N/A
25.0 m	30	69	-130	28	65	-132	2	4	-100
Enretech-Sand									
8.5 m	50	40	20	45	40	11	5	0	100
13.1 m	20	55	-175	13	15	-15	7	40	-471
16.4 m	30	40	-33	25	37	-48	5	3	40
20.6 m	45	45	0	45	35	22	0	10	N/A
25.0 m	30	40	-33	28	39	-39	2	1	50

FILTRATION MEDIA EVALUATION: PreSettled Influent

Fall 1995

COLOR (Continued)

SAMPLE GROUP NAME	Unfiltered Fraction (Apparent HACH Units)			Filtered Fraction (Apparent HACH Units)			Particulate Fraction (Apparent HACH Units)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand									
8.5 m	50	30	40	45	40	11	5	-10	300
13.1 m	20	60	-200	13	15	-15	7	45	-543
16.4 m	30	40	-33	25	40	-60	5	0	100
20.6 m	45	45	0	45	42	7	0	3	N/A
25.0 m	30	60	-100	28	35	-25	2	25	-1150
Sand									
8.5 m	50	50	0	45	35	22	5	15	-200
13.1 m	20	55	-175	13	25	-92	7	30	-329
16.4 m	30	40	-33	25	30	-20	5	10	-100
20.6 m	45	45	0	45	35	22	0	10	N/A
25.0 m	30	54	-80	28	28	0	2	26	-1200
Gunderboom Fabric									
8.5 m	50	45	10	45	30	33	5	15	-200
13.1 m	20	15	25	13	15	-15	7	0	100
16.4 m	30	40	-33	25	30	-20	5	10	-100
20.6 m	45	30	33	45	30	33	0	0	N/A
25.0 m	30	31	-3	28	23	18	2	8	-300
EMCON Fabric									
8.5 m	50	45	10	45	30	33	5	15	-200
13.1 m	20	25	-25	13	10	23	7	15	-114
16.4 m	30	45	-50	25	45	-80	5	0	100
20.6 m	45	30	33	45	30	33	0	0	N/A
25.0 m	30	31	-3	28	26	7	2	5	-150



Carbon-Sand

Wilcoxon P = 0.1250

Peat-Sand

Wilcoxon P = 0.0313

Zeolite-Sand

Wilcoxon P = 0.0625

Compost-Sand

Wilcoxon P = 0.0313

Enretech-Sand

Wilcoxon P = 0.1875

Forest-Sand

Wilcoxon P = 0.1875

Sand

Wilcoxon P = 0.1250

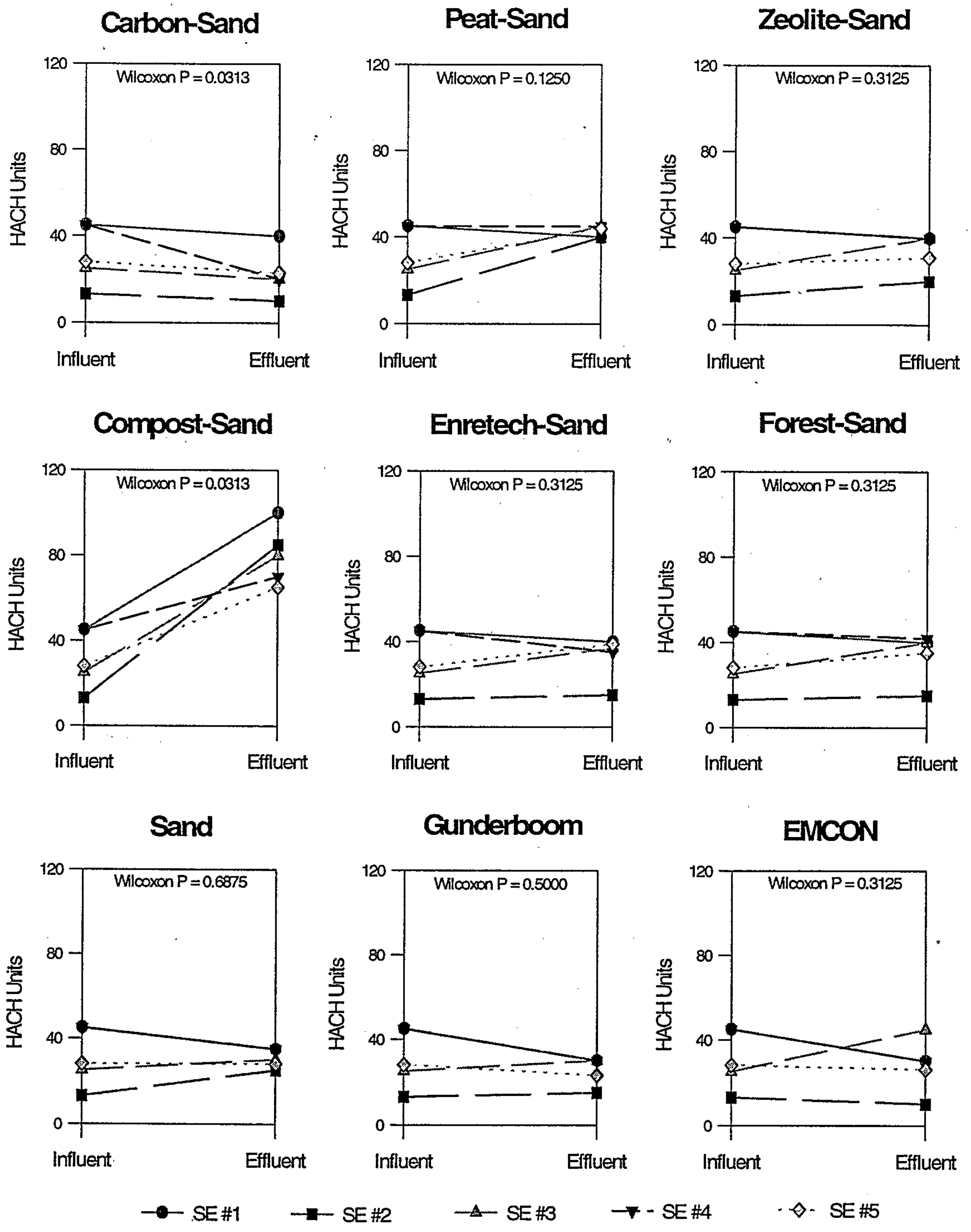
Gunderboom

Wilcoxon P = 0.3125

EMCON

Wilcoxon P = 0.5000

COLOR: PreSettled Influent
Unfiltered Fraction



COLOR: PreSettled Influent
Filtered Fraction

COLOR

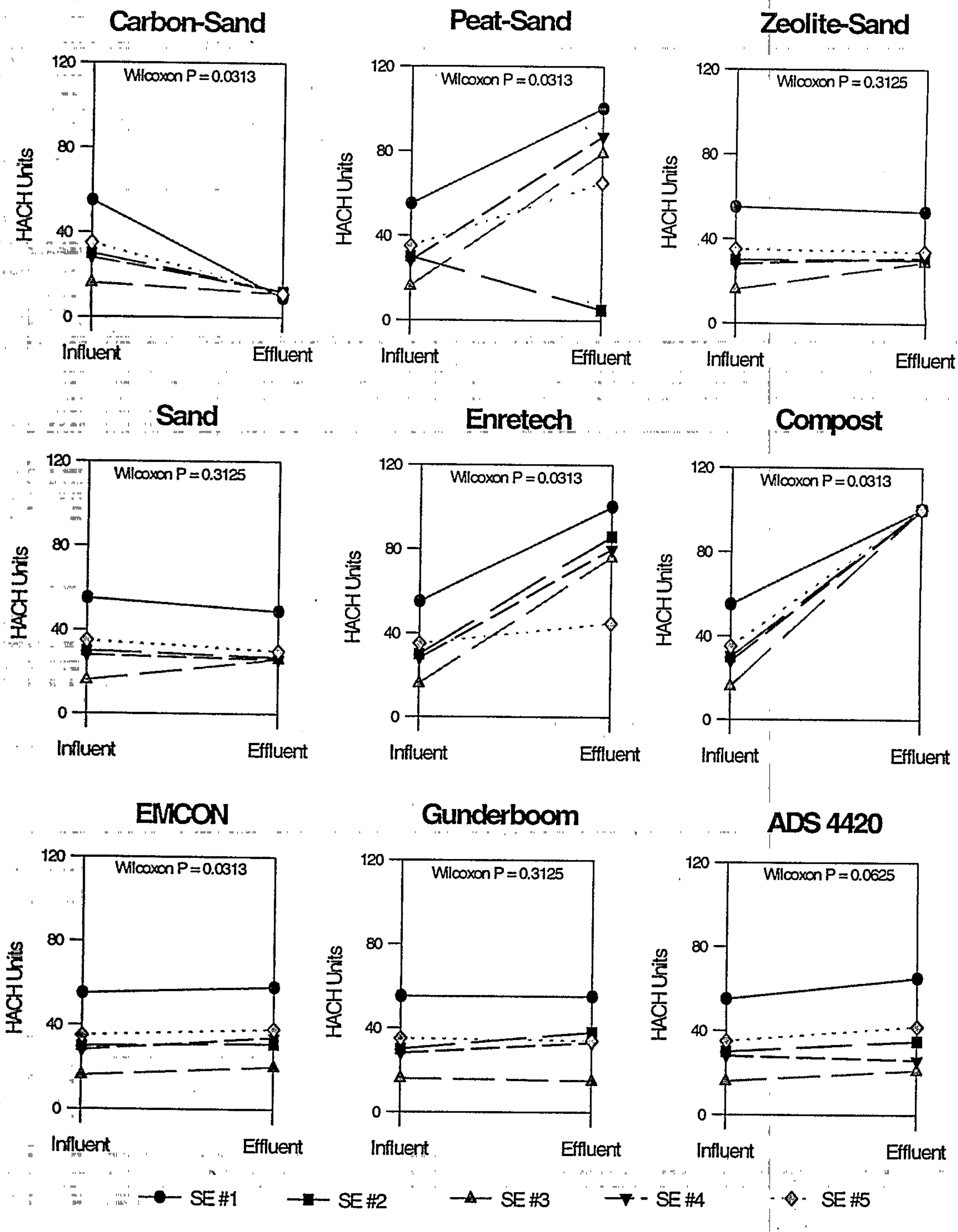
FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Unfiltered Fraction (HACH Units)			Filtered Fraction (HACH Units)			Particulate Fraction (HACH Units)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
1.1 m	55	9	84	44	9	80	11	0	100
2.2 m	30	12	60	20	3	85	10	9	10
3.3 m	16	11	31	30	20	33	0	0	N/A
4.4 m	28	12	57	23	15	35	5	0	100
5.5 m	35	11	69	40	6	85	0	5	N/A
Peat-Sand									
1.1 m	55	100	-82	44	91	-107	11	9	18
2.2 m	30	95	-217	20	60	-200	10	35	-250
3.3 m	16	79	-394	30	60	-100	0	19	N/A
4.4 m	28	87	-211	23	62	-170	5	25	-400
5.5 m	35	65	-86	40	45	-13	0	20	N/A
Zeolite-Sand									
1.1 m	55	53	4	44	31	30	11	22	-100
2.2 m	30	30	0	20	30	-50	10	0	100
3.3 m	16	29	-81	30	30	0	0	0	N/A
4.4 m	28	31	-11	23	27	-17	5	4	20
5.5 m	35	34	3	40	30	25	0	4	N/A
Sand									
1.1 m	55	49	11	44	29	34	11	20	-82
2.2 m	30	27	10	20	30	-50	10	0	100
3.3 m	16	26	-63	30	30	0	0	0	N/A
4.4 m	28	26	7	23	20	13	5	6	-20
5.5 m	35	30	14	40	28	30	0	2	N/A
Enretech									
1.1 m	55	100	-82	44	100	-127	11	0	100
2.2 m	30	86	-187	20	86	-330	10	0	100
3.3 m	16	76	-375	30	25	17	0	51	N/A
4.4 m	28	80	-186	23	58	-152	5	22	-340
5.5 m	35	45	-29	40	38	5	0	7	N/A

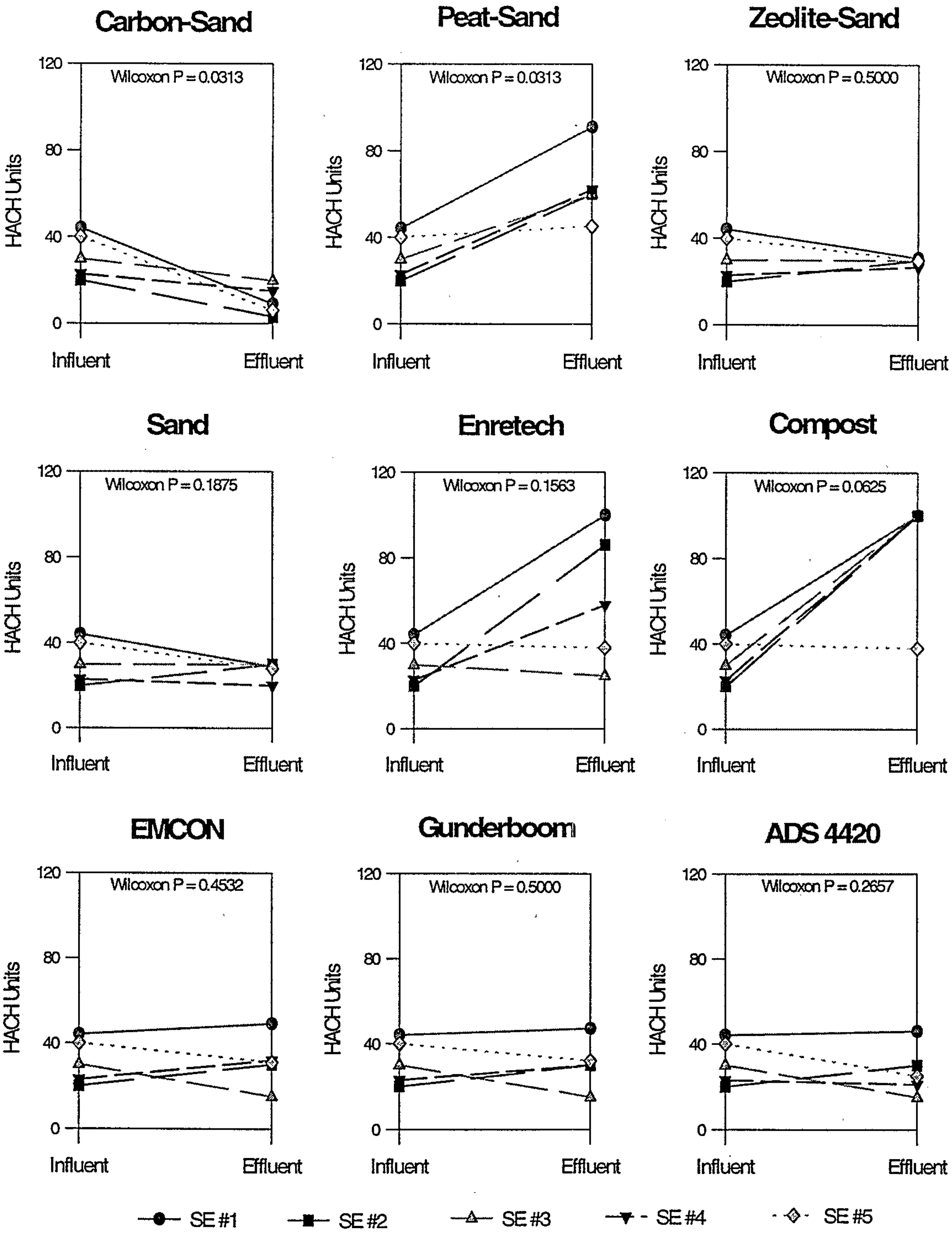
COLOR (Continued)

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Unfiltered Fraction (HACH Units)			Filtered Fraction (HACH Units)			Particulate Fraction (HACH Units)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost									
1.1 m	55	100	-82	44	100	-127	11	0	100
2.2 m	30	100	-233	20	100	-400	10	0	100
3.3 m	16	100	-525	30	100	-233	0	0	N/A
4.4 m	28	100	-257	23	100	-335	5	0	100
5.5 m	35	100	-186	40	38	5	0	62	N/A
EMCON Fabric									
1.1 m	55	58	-5	44	49	-11	11	9	18
2.2 m	30	31	-3	20	30	-50	10	1	90
3.3 m	16	20	-25	30	15	50	0	5	N/A
4.4 m	28	34	-21	23	32	-39	5 ?	2	60
5.5 m	35	38	-9	40	31	23	0	7	N/A
Gunderboom Fabric									
1.1 m	55	55	0	44	47	-7	11	8	27
2.2 m	30	38	-27	20	30	-50	10	8	20
3.3 m	16	15	6	30	15	50	0	0	N/A
4.4 m	28	33	-18	23	30	-30	5	3	40
5.5 m	35	34	3	40	32	20	0	2	N/A
ADS 4420 Fabric									
1.1 m	55	65	-18	44	46	-5	11	19	-73
2.2 m	30	35	-17	20	30	-50	10	5	50
3.3 m	16	21	-31	30	15	50	0	6	N/A
4.4 m	28	26	7	23	21	9	5	5	0
5.5 m	35	42	-20	40	25	38	0	17	N/A



COLOR: Unpretreated Influent
Unfiltered Fraction



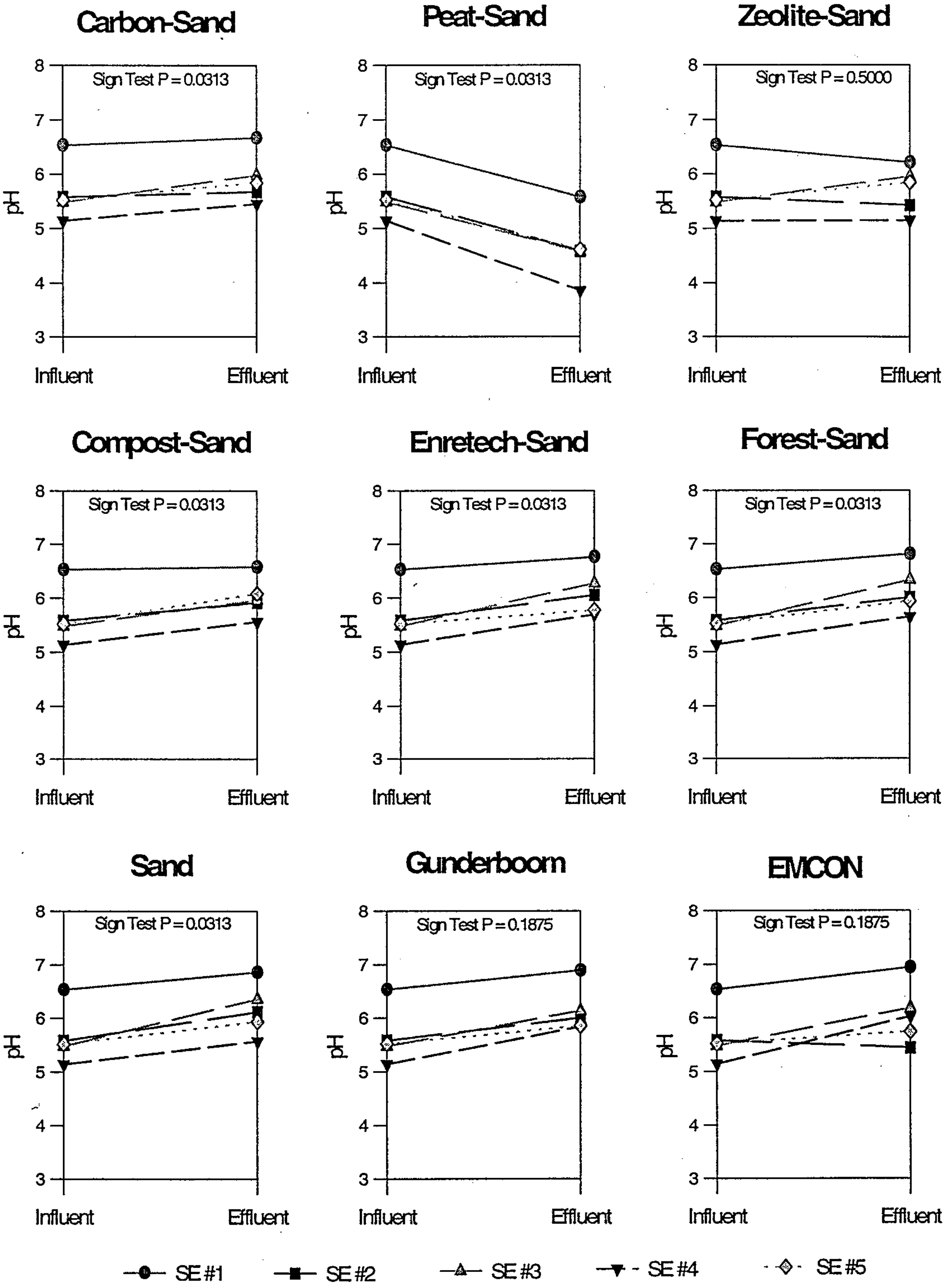
COLOR: Unpretreated Influent
Filtered Fraction

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

pH

SAMPLE GROUP NAME	pH		
	Influent	Effluent	% Decrease
Activated Carbon-Sand			
8.5 m	6.53	6.67	2
13.1 m	5.58	5.67	2
16.4 m	5.48	5.98	9
20.6 m	5.14	5.45	6
25.0 m	5.52	5.84	6
Peat-Sand			
8.5 m	6.53	5.57	-15
13.1 m	5.58	4.59	-18
16.4 m	5.48	4.58	-16
20.6 m	5.14	3.85	-25
25.0 m	5.52	4.62	-16
Zeolite-Sand			
8.5 m	6.53	6.25	-4
13.1 m	5.58	5.43	-3
16.4 m	5.48	5.96	9
20.6 m	5.14	5.16	0
25.0 m	5.52	5.85	6
Compost-Sand			
8.5 m	6.53	6.58	1
13.1 m	5.58	5.91	6
16.4 m	5.48	5.96	9
20.6 m	5.14	5.56	8
25.0 m	5.52	6.08	10
Enretech-Sand			
8.5 m	6.53	6.76	4
13.1 m	5.58	6.05	8
16.4 m	5.48	6.27	14
20.6 m	5.14	5.69	11
25.0 m	5.52	5.77	5

SAMPLE GROUP NAME	pH		
	Influent	Effluent	% Decrease
Forest Products-Sand			
8.5 m	6.53	6.82	4
13.1 m	5.58	6.01	8
16.4 m	5.48	6.34	16
20.6 m	5.14	5.65	10
25.0 m	5.52	5.94	8
Sand			
8.5 m	6.53	6.86	5
13.1 m	5.58	6.11	9
16.4 m	5.48	6.35	16
20.6 m	5.14	5.57	8
25.0 m	5.52	5.93	7
Gunderboom Fabric			
8.5 m	6.53	6.89	6
13.1 m	5.58	6.00	8
16.4 m	5.48	6.13	12
20.6 m	5.14	5.84	14
25.0 m	5.52	5.85	6
EMCON Fabric			
8.5 m	6.53	6.94	6
13.1 m	5.58	5.44	-3
16.4 m	5.48	6.18	13
20.6 m	5.14	6.02	17
25.0 m	5.52	5.74	4



pH: PreSettled Influent

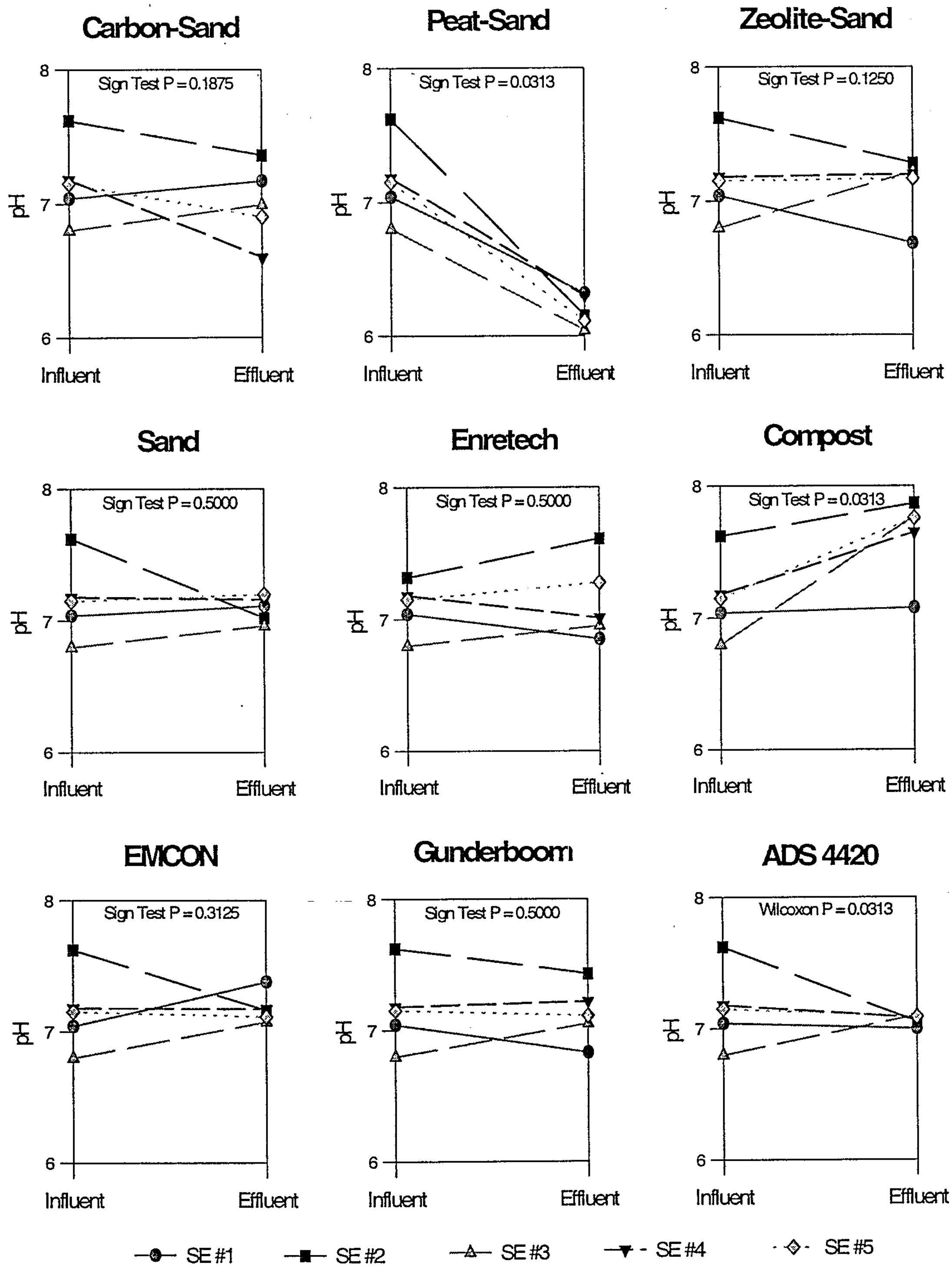
FILTRATION MEDIA EVALUATION: Unpretreated Influent

Summer 1994

pH

SAMPLE GROUP NAME	pH		
	Influent	Effluent	% Decrease
Activated Carbon-Sand			
1.1 m	7.04	7.17	-2
2.2 m	7.62	7.36	3
3.3 m	6.80	6.99	3
4.4 m	7.18	6.60	8
5.5 m	7.15	6.90	3
Peat-Sand			
1.1 m	7.04	6.32	-10
2.2 m	7.62	6.15	-19
3.3 m	6.80	6.04	-11
4.4 m	7.18	6.30	12
5.5 m	7.15	6.11	N/A
Zeolite-Sand			
1.1 m	7.04	6.69	-5
2.2 m	7.32	7.28	1
3.3 m	6.80	7.22	-6
4.4 m	7.18	7.20	0
5.5 m	7.15	7.17	0
Sand			
1.1 m	7.04	7.11	-1
2.2 m	7.32	7.02	4
3.3 m	6.80	6.96	2
4.4 m	7.18	7.16	0
5.5 m	7.15	7.20	-1
Enretech			
1.1 m	7.04	6.85	-3
2.2 m	7.32	7.61	-4
3.3 m	6.80	6.95	2
4.4 m	7.18	7.01	2
5.5 m	7.15	7.28	-2

SAMPLE GROUP NAME	pH		
	Influent	Effluent	% Decrease
Compost			
1.1 m	7.04	7.08	-1
2.2 m	7.62	7.87	-3
3.3 m	6.80	7.77	-14
4.4 m	7.18	7.65	-7
5.5 m	7.15	7.76	-9
EMCON Fabric			
1.1 m	7.04	7.38	-5
2.2 m	7.62	7.16	6
3.3 m	6.80	7.07	4
4.4 m	7.18	7.17	0
5.5 m	7.15	7.11	1
Gunderboom Fabric			
1.1 m	7.04	6.83	-3
2.2 m	7.62	7.43	2
3.3 m	6.80	7.05	4
4.4 m	7.18	7.22	-1
5.5 m	7.15	7.11	1
ADS 4420 Fabric			
1.1 m	7.04	7.00	1
2.2 m	7.62	7.05	7
3.3 m	6.80	7.10	4
4.4 m	7.18	7.08	1
5.5 m	7.15	7.09	1



pH: Unpretreated Influent

Appendix D:
Anions

Carbonate
Bicarbonate
Fluoride
Chloride
Nitrite
Nitrate
Phosphate
Sulfate

ANIONS

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Carbonate (mg/L)			Bicarbonate (mg/L)			Fluoride (mg/L) MDL = 0.027 mg/L			Chloride (mg/L) MDL = 0.080 mg/L		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	0.005	0.004	29	57.810	40.388	30	0.024	0.018	25	1.982	2.504	-26
13.1 m	0.004	0.001	82	25.538	15.245	40	0.133	ND	100	1.695	1.772	-5
16.4 m	0.014	0.004	72	43.742	26.329	40	0.134	0.144	-7	1.448	1.833	-27
20.6 m	0.002	0.001	57	30.687	21.779	29	0.010	0.011	-10	2.016	2.028	-1
25.0 m	0.003	0.004	-7	24.746	30.488	-23	0.020	0.007	65	2.158	2.164	0
Peat-Sand												
8.5 m	0.005	0.000	100	57.810	0.000	100	0.024	0.084	-250	1.982	1.627	18
13.1 m	0.004	0.000	100	25.538	0.000	100	0.133	ND	100	1.695	1.284	24
16.4 m	0.014	0.000	100	43.742	0.000	100	0.134	0.007	95	1.448	1.217	16
20.6 m	0.002	0.000	100	30.687	0.000	100	0.010	0.120	-1100	2.016	1.679	17
25.0 m	0.003	0.000	100	24.746	0.000	100	0.020	ND	100	2.158	1.936	10
Zeolite-Sand												
8.5 m	0.005	0.002	60	57.810	58.210	-1	0.024	0.037	-54	1.982	1.826	8
13.1 m	0.004	0.002	54	25.538	30.094	-18	0.133	ND	100	1.695	1.507	11
16.4 m	0.014	0.003	78	43.742	41.775	4	0.134	0.007	95	1.448	1.413	2
20.6 m	0.002	0.002	6	30.687	30.885	-1	0.010	0.007	30	2.016	1.856	8
25.0 m	0.003	0.036	-949	24.746	68.271	-176	0.020	0.015	25	2.158	2.030	6
Compost-Sand												
8.5 m	0.005	0.018	-252	57.810	84.923	-47	0.024	0.279	-1063	1.982	2.566	-29
13.1 m	0.004	0.006	-83	25.538	44.543	-74	0.133	0.018	86	1.695	1.589	6
16.4 m	0.014	0.004	69	43.742	54.445	-24	0.134	0.053	60	1.448	1.723	-19
20.6 m	0.002	0.008	-226	30.687	46.719	-52	0.010	0.023	-130	2.016	2.026	0
25.0 m	0.003	0.006	-78	24.746	56.621	-129	0.020	0.023	-15	2.158	2.258	-5
Enretech-Sand												
8.5 m	0.005	0.009	-64	57.810	59.985	-4	0.024	0.041	-71	1.982	4.526	-128
13.1 m	0.004	0.003	15	25.538	32.667	-28	0.133	0.009	93	1.695	3.258	-92
16.4 m	0.014	0.032	-128	43.742	42.534	3	0.134	0.030	78	1.448	1.329	8
20.6 m	0.002	0.008	-253	30.687	34.242	-12	0.010	0.010	0	2.016	2.103	-4
25.0 m	0.003	0.003	24	24.746	36.825	-49	0.020	0.018	10	2.158	2.092	3

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

ANIONS (Continued)

SAMPLE GROUP NAME	Carbonate (mg/L)			Bicarbonate (mg/L)			Fluoride (mg/L) MDL = 0.027 mg/L			Chloride (mg/L) MDL = 0.080 mg/L		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	0.005	0.010	-99	57.810	60.379	-4	0.024	0.161	-571	1.982	1.826	8
13.1 m	0.004	0.003	23	25.538	29.697	-16	0.133	0.006	95	1.695	1.601	6
16.4 m	0.014	0.017	-24	43.742	56.807	-30	0.134	0.109	19	1.448	1.585	-9
20.6 m	0.002	0.007	-188	30.687	32.068	-4	0.010	0.014	-40	2.016	2.695	-34
25.0 m	0.003	0.007	-101	24.746	35.835	-45	0.020	0.018	10	2.158	1.956	9
Sand												
8.5 m	0.005	0.007	-28	57.810	61.769	-7	0.024	0.028	-17	1.982	1.900	4
13.1 m	0.004	0.005	-45	25.538	30.882	-21	0.133	0.120	10	1.695	1.475	13
16.4 m	0.014	0.004	73	43.742	40.784	7	0.134	0.011	92	1.448	1.504	-4
20.6 m	0.002	0.004	-78	30.687	30.685	0	0.010	0.228	-2180	2.016	2.078	-3
25.0 m	0.003	0.003	24	24.746	35.637	-44	0.020	0.019	5	2.158	2.017	7
Gunderboom Fabric												
8.5 m	0.005	0.008	-61	57.810	65.727	-14	0.024	0.025	-4	1.982	2.424	-22
13.1 m	0.004	0.003	26	25.538	28.509	-12	0.133	0.451	-239	1.695	3.016	-78
16.4 m	0.014	0.002	83	43.742	37.617	14	0.134	0.097	28	1.448	1.608	-11
20.6 m	0.002	0.006	-140	30.687	30.683	0	0.010	0.010	0	2.016	1.830	9
25.0 m	0.003	0.004	-6	24.746	34.646	-40	0.020	0.017	15	2.158	2.134	1
EMCON Fabric												
8.5 m	0.005	0.006	-20	57.810	60.383	-4	0.024	0.032	-33	1.982	1.829	8
13.1 m	0.004	0.003	4	25.538	28.706	-12	0.133	0.007	95	1.695	2.110	-24
16.4 m	0.014	0.007	46	43.742	40.780	7	0.134	0.018	87	1.448	1.430	1
20.6 m	0.002	0.009	-275	30.687	32.658	-6	0.010	0.008	20	2.016	1.824	10
25.0 m	0.003	0.003	16	24.746	35.241	-42	0.020	0.247	-1135	2.158	2.259	-5

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall, 1995

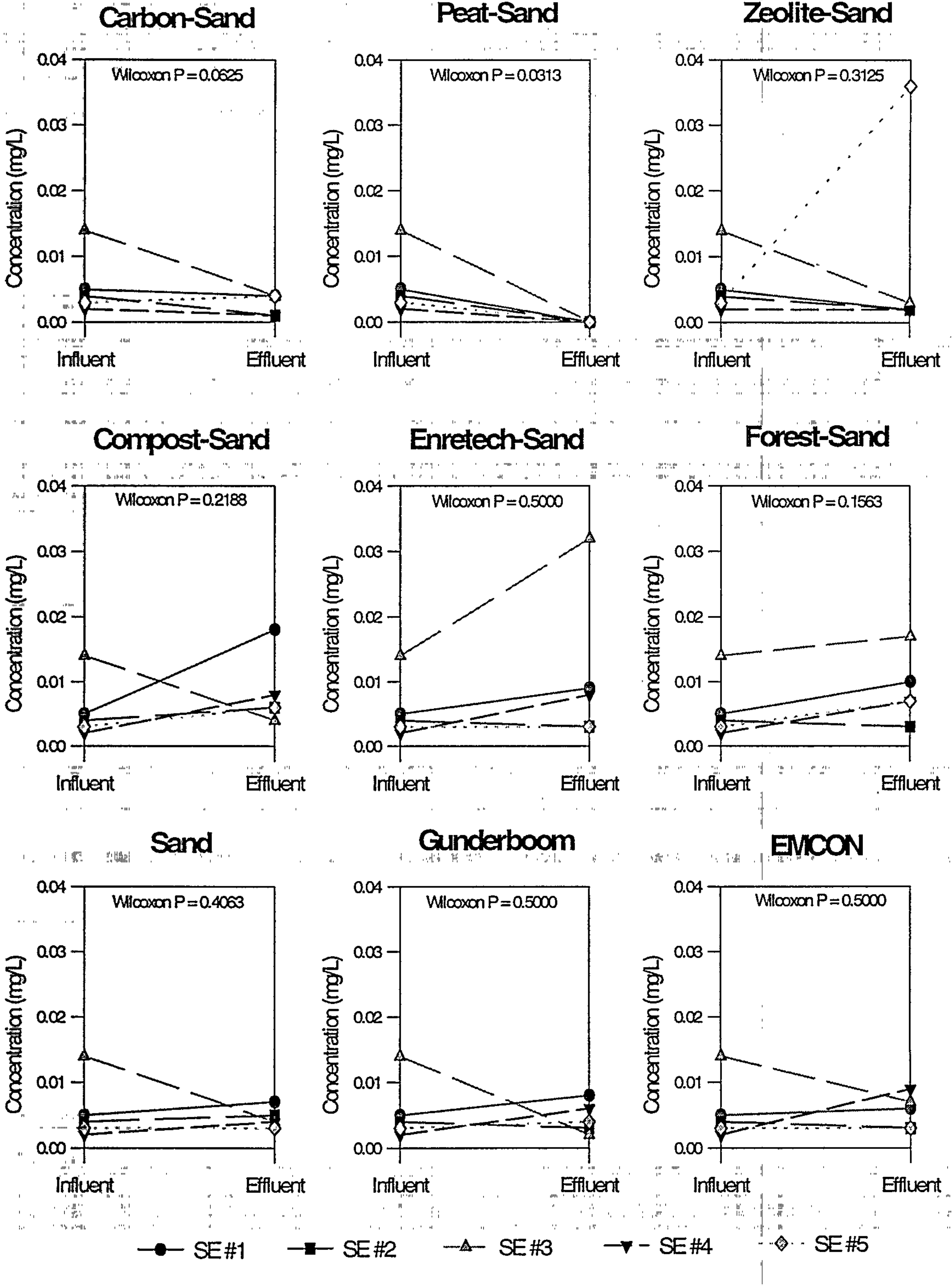
ANIONS (Continued)

SAMPLE GROUP NAME	Nitrite (mg/L) MDL = 0.111 mg/L			Nitrate (mg/L) MDL = 0.040 mg/L			Phosphate (mg/L) MDL = 0.084 mg/L			Sulfate (mg/L) MDL = 0.083 mg/L		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	ND	ND	N/A	ND	0.084	N/A	ND	ND	N/A	7.583	22.318	-194
13.1 m	0.060	ND	100	1.470	ND	100	ND	ND	N/A	5.258	18.101	-244
16.4 m	ND	ND	N/A	1.508	ND	100	ND	ND	N/A	6.734	15.961	-137
20.6 m	ND	ND	N/A	1.974	0.116	94	ND	ND	N/A	7.879	11.383	-44
25.0 m	ND	ND	N/A	1.866	0.142	92	ND	ND	N/A	7.522	10.980	-46
Peat-Sand												
8.5 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	7.583	7.237	5
13.1 m	0.060	ND	100	1.470	1.385	6	ND	ND	N/A	5.258	4.941	6
16.4 m	ND	ND	N/A	1.508	1.560	-3	ND	ND	N/A	6.734	6.247	7
20.6 m	ND	ND	N/A	1.974	1.875	5	ND	ND	N/A	7.879	7.144	9
25.0 m	ND	ND	N/A	1.866	2.137	-15	ND	ND	N/A	7.522	7.748	-3
Zeolite-Sand												
8.5 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	7.583	7.494	1
13.1 m	0.060	0.101	-68	1.470	1.614	-10	ND	ND	N/A	5.258	5.725	-9
16.4 m	ND	ND	N/A	1.508	1.455	4	ND	ND	N/A	6.734	6.706	0
20.6 m	ND	ND	N/A	1.974	1.697	14	ND	ND	N/A	7.879	7.489	5
25.0 m	ND	ND	N/A	1.866	1.952	-5	ND	ND	N/A	7.522	8.298	-10
Compost-Sand												
8.5 m	ND	ND	N/A	ND	0.102	N/A	ND	1.516	N/A	7.583	7.718	-2
13.1 m	0.060	0.052	13	1.470	3.797	-158	ND	1.172	N/A	5.258	5.288	-1
16.4 m	ND	ND	N/A	1.508	0.864	43	ND	0.766	N/A	6.734	6.627	2
20.6 m	ND	ND	N/A	1.974	1.315	33	ND	0.548	N/A	7.879	7.201	9
25.0 m	ND	ND	N/A	1.866	2.314	-24	ND	0.962	N/A	7.522	7.883	-5
Enretech-Sand												
8.5 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	7.583	7.425	2
13.1 m	0.060	ND	100	1.470	1.324	10	ND	ND	N/A	5.258	5.459	-4
16.4 m	ND	ND	N/A	1.508	1.365	9	ND	ND	N/A	6.734	6.261	7
20.6 m	ND	ND	N/A	1.974	1.807	8	ND	ND	N/A	7.879	7.733	2
25.0 m	ND	ND	N/A	1.866	1.989	-7	ND	ND	N/A	7.522	7.395	2

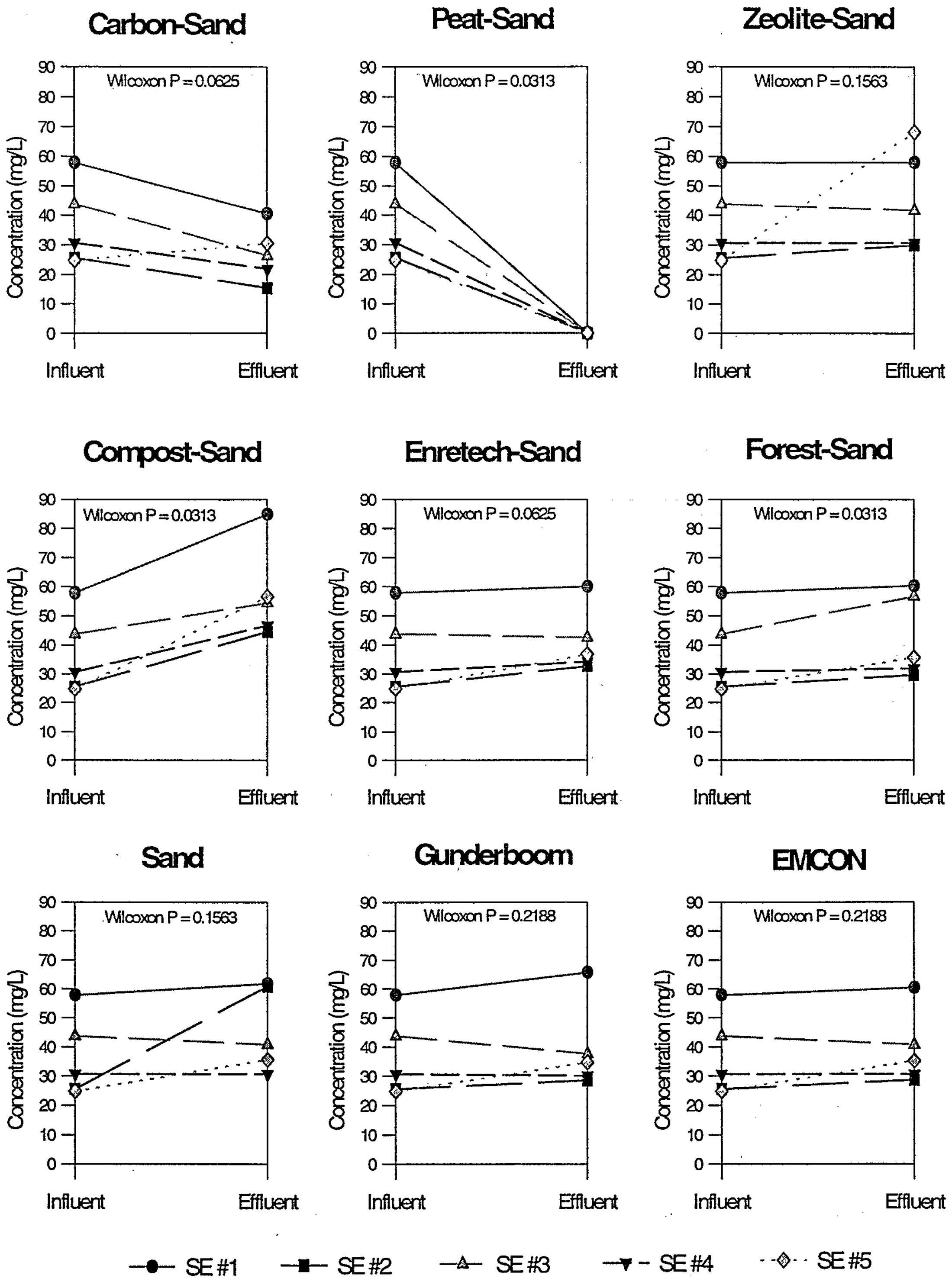
FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall, 1995

ANIONS (Continued)

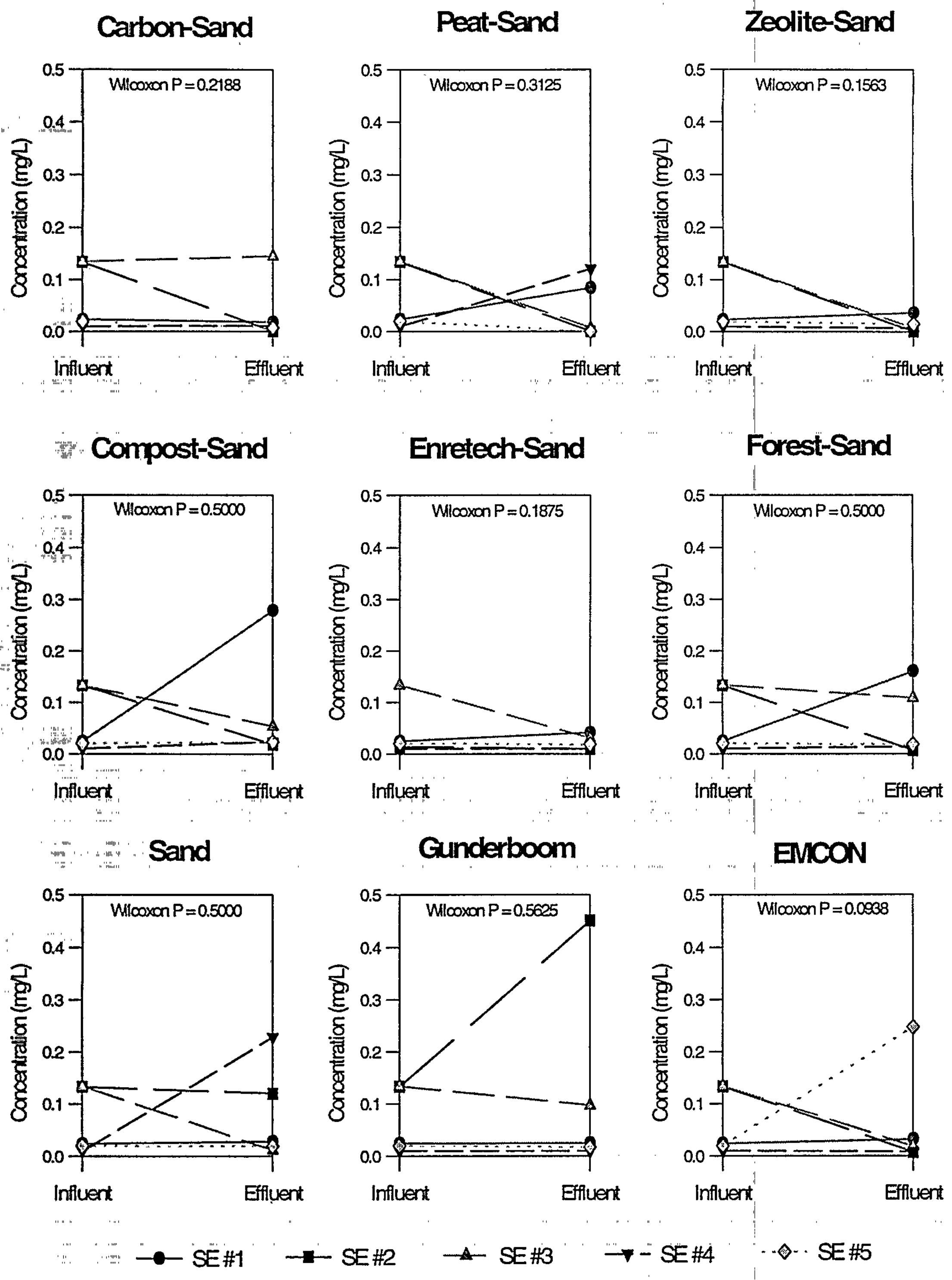
SAMPLE GROUP NAME	Nitrite (mg/L) MDL = 0.111 mg/L			Nitrate (mg/L) MDL = 0.040 mg/L			Phosphate (mg/L) MDL = 0.084 mg/L			Sulfate (mg/L) MDL = 0.083 mg/L		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	7.583	7.331	3
13.1 m	0.060	0.052	13	1.470	1.403	5	ND	ND	N/A	5.258	5.579	-6
16.4 m	ND	ND	N/A	1.508	1.402	7	ND	ND	N/A	6.734	6.337	6
20.6 m	ND	0.048	N/A	1.974	1.802	9	ND	ND	N/A	7.879	7.561	4
25.0 m	ND	ND	N/A	1.866	1.936	-4	ND	ND	N/A	7.522	7.590	-1
Sand												
8.5 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	7.583	7.536	1
13.1 m	0.060	0.055	8	1.470	1.482	-1	ND	ND	N/A	5.258	5.213	1
16.4 m	ND	ND	N/A	1.508	1.417	6	ND	ND	N/A	6.734	6.910	-3
20.6 m	ND	ND	N/A	1.974	1.879	5	ND	ND	N/A	7.879	8.659	-10
25.0 m	ND	ND	N/A	1.866	2.074	-11	ND	ND	N/A	7.522	7.696	-2
Gunderboom Fabric												
8.5 m	ND	ND		ND	0.058	N/A	ND	ND	N/A	7.583	7.491	1
13.1 m	0.060	ND	100	1.470	>100	N/A	ND	ND	N/A	5.258	6.355	-21
16.4 m	ND	ND	N/A	1.508	1.627	-8	ND	ND	N/A	6.734	6.424	5
20.6 m	ND	0.036	N/A	1.974	2.113	-7	ND	ND	N/A	7.879	7.804	1
25.0 m	ND	ND	N/A	1.866	1.979	-6	ND	ND	N/A	7.522	7.601	-1
EMCON Fabric												
8.5 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	7.583	7.152	6
13.1 m	0.060	0.059	2	1.470	1.499	-2	ND	ND	N/A	5.258	4.955	6
16.4 m	ND	ND	N/A	1.508	1.607	-7	ND	ND	N/A	6.734	6.873	-2
20.6 m	ND	ND	N/A	1.974	1.962	1	ND	ND	N/A	7.879	7.545	4
25.0 m	ND	ND	N/A	1.866	2.157	-16	ND	ND	N/A	7.522	7.987	-6



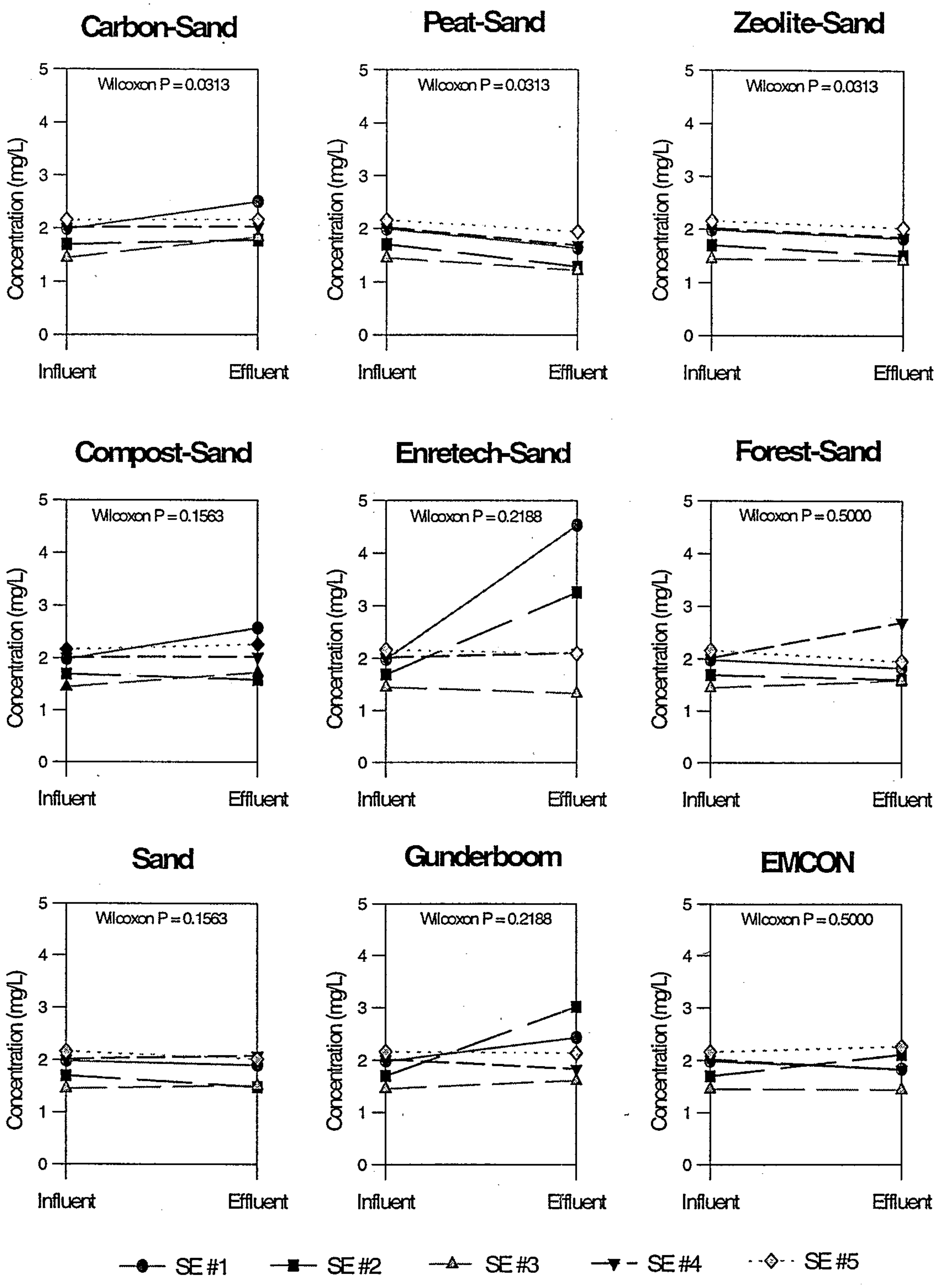
CARBONATE: Pre-Settled Influent



BICARBONATE: Pre-Settled Influent



FLUORIDE: Pre-Settled Influent



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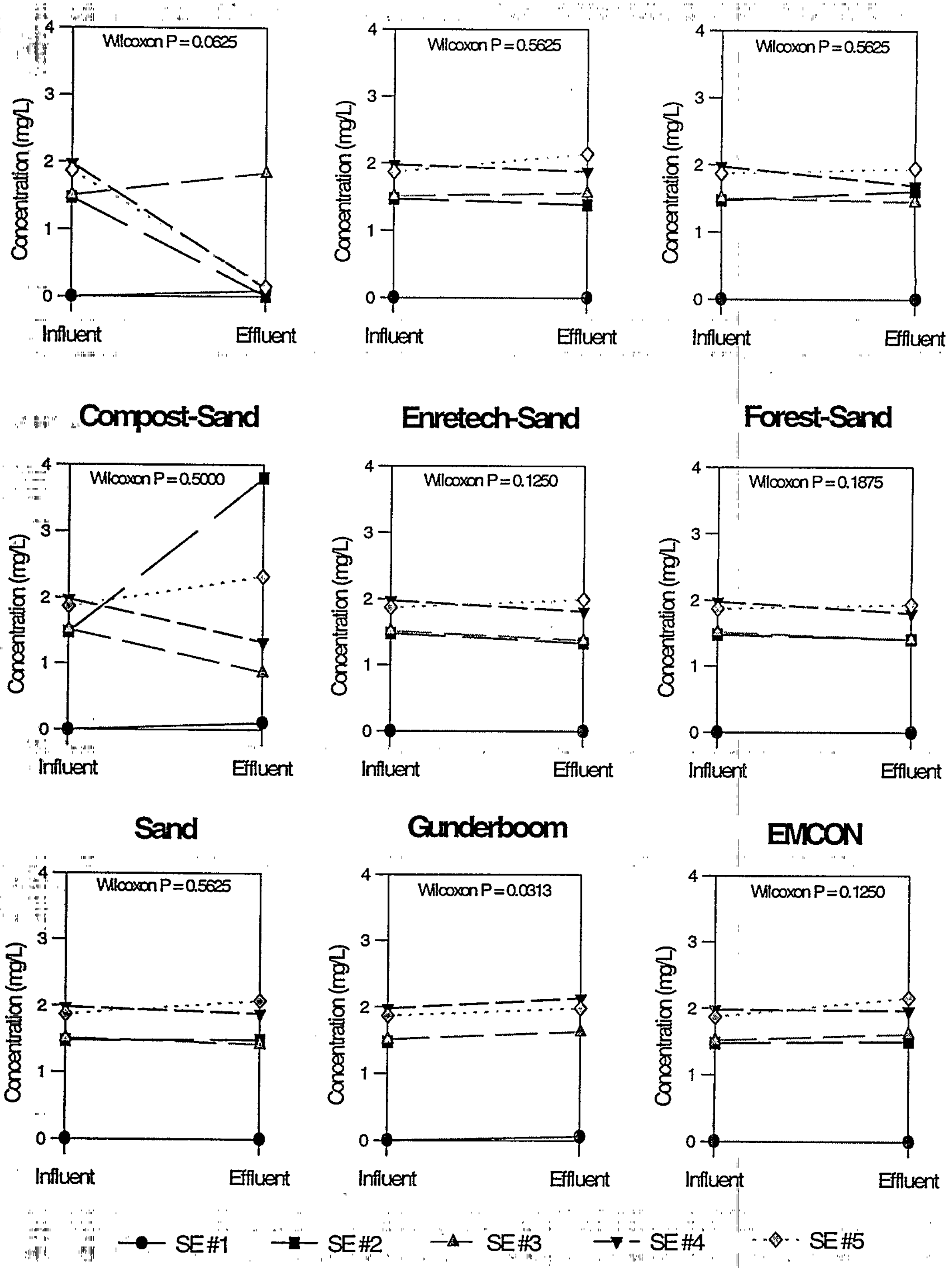
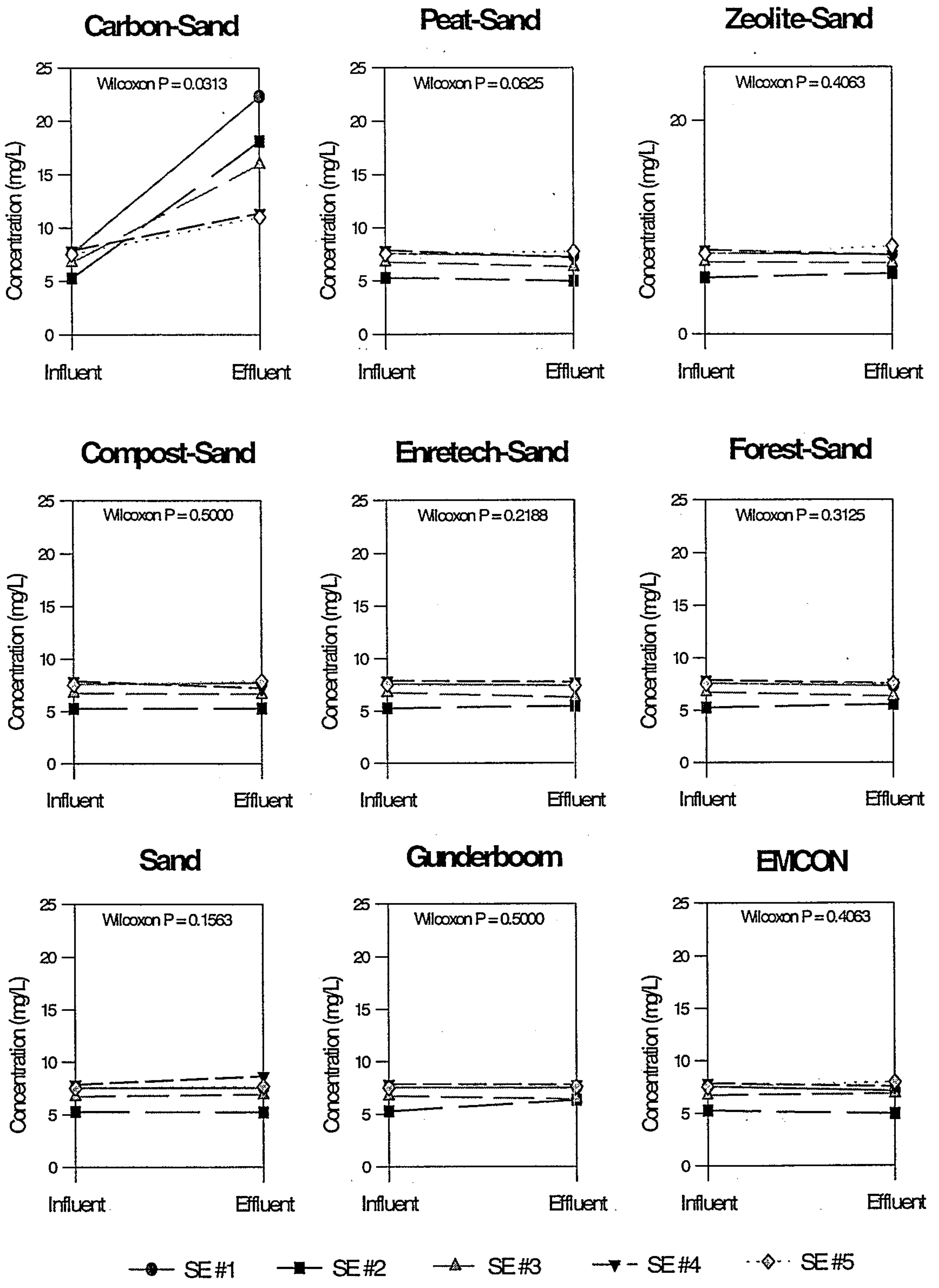


NITRATE: Pre-Settled Influent



SULFATE: Pre-Settled Influent

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

ANIONS

SAMPLE GROUP NAME	Carbonate (mg/L)			Bicarbonate (mg/L)			Fluoride (mg/L)			Chloride (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
1.1 m	0.034	0.017	50	51.145	49.283	4	0.053	0.028	47	4.067	6.778	-67
2.2 m	0.090	0.031	66	98.014	50.654	48	0.083	0.032	61	6.497	7.385	-14
3.3 m	0.010	0.004	60	35.727	20.092	44	0.021	0.119	-467	1.389	3.743	-169
4.4 m	0.028	0.005	82	42.737	14.052	67	0.039	ND	100	1.208	3.060	-153
5.5 m	0.074	0.010	86	48.230	20.579	57	0.027	0.015	44	1.405	3.060	-118
Peat-Sand												
1.1 m	0.034	0.004	88	51.145	36.229	29	0.053	0.008	85	4.067	14.979	-268
2.2 m	0.090	0.002	98	98.014	21.481	78	0.083	ND	100	6.497	8.250	-27
3.3 m	0.010	0.002	80	35.727	13.066	63	0.021	ND	100	1.389	1.192	14
4.4 m	0.028	0.005	82	42.737	57.810	-35	0.039	ND	100	1.208	1.386	-15
5.5 m	0.074	broken	N/A	48.230	broken	N/A	0.027	ND	100	1.405	1.464	-4
Zeolite-Sand												
1.1 m	0.034	0.060	-76	51.145	74.582	-46	0.053	0.051	4	4.067	3.668	10
2.2 m	0.090	0.069	23	98.014	98.334	0	0.083	0.048	42	6.497	6.744	-4
3.3 m	0.010	0.017	-70	35.727	41.957	-17	0.021	0.023	-10	1.389	1.596	-15
4.4 m	0.028	0.042	-50	42.737	45.889	-7	0.039	0.044	-13	1.208	1.492	-24
5.5 m	0.074	0.056	24	48.230	49.636	-3	0.027	0.062	-130	1.405	7.219	-414
Sand												
1.1 m	0.034	0.042	-24	51.145	77.373	-51	0.053	0.036	32	4.067	3.789	7
2.2 m	0.090	0.061	32	98.014	90.917	7	0.083	0.076	8	6.497	6.371	2
3.3 m	0.010	0.014	-40	35.727	39.386	-10	0.021	0.034	-62	1.389	1.434	-3
4.4 m	0.028	0.047	-68	42.737	73.210	-71	0.039	0.033	15	1.208	1.441	-19
5.5 m	0.074	0.085	-15	48.230	49.604	-3	0.027	0.083	-207	1.405	1.551	-10
Enretech												
1.1 m	0.034	0.024	29	51.145	125.898	-146	0.053	0.041	23	4.067	7.817	-92
2.2 m	0.090	0.099	-10	98.014	126.023	-29	0.083	0.029	65	6.497	8.688	-34
3.3 m	0.010	0.025	-150	35.727	74.916	-110	0.021	0.049	-133	1.389	1.741	-25
4.4 m	0.028	0.082	-193	42.737	48.220	-13	0.039	0.042	-8	1.208	1.441	-19
5.5 m	0.074	0.069	7	48.230	68.706	-42	0.027	0.102	-278	1.405	2.028	-44

ANIONS (Continued)

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Carbonate (mg/L)			Bicarbonate (mg/L)			Fluoride (mg/L)			Chloride (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost												
1.1 m	0.034	0.180	-429	51.145	179.103	-250	0.053	0.138	-160	4.067	4.425	-9
2.2 m	0.090	0.794	-782	98.014	352.228	-259	0.083	0.180	-117	6.497	6.190	5
3.3 m	0.010	0.271	-2610	35.727	173.960	-387	0.021	0.094	-348	1.389	1.657	-19
4.4 m	0.028	0.813	-2804	42.737	207.462	-385	0.039	0.248	-536	1.208	1.676	-39
5.5 m	0.074	0.496	-570	48.230	178.877	-271	0.027	0.161	-496	1.405	2.119	-51
EMCON Fabric												
1,1 m	0.034	0.036	-6	51.145	78.172	-53	0.053	0.033	38	4.067	3.691	9
2.2 m	0.090	0.078	13	98.014	95.650	2	0.083	0.077	7	6.497	6.100	6
3.3 m	0.010	0.013	-30	35.727	37.011	-4	0.021	0.021	0	1.389	1.311	6
4.4 m	0.028	0.038	-36	42.737	42.527	0	0.039	0.027	31	1.208	1.210	0
5.5 m	0.074	0.032	57	48.230	42.930	11	0.027	0.035	-30	1.405	1.580	-12
Gunderboom Fabric												
1.1 m	0.034	0.042	-24	51.145	74.997	-47	0.053	0.043	19	4.067	2.863	30
2.2 m	0.090	0.081	10	98.014	95.646	2	0.083	0.040	52	6.497	5.572	14
3.3 m	0.010	0.014	-40	35.727	35.624	0	0.021	0.016	24	1.389	1.405	-1
4.4 m	0.028	0.034	-21	42.737	44.116	-3	0.039	0.028	28	1.208	1.344	-11
5.5 m	0.074	0.055	26	48.230	50.628	-5	0.027	0.025	7	1.405	1.391	1
ADS 4420 Fabric												
1.1 m	0.034	0.045	-32	51.145	71.826	-40	0.053	0.034	36	4.067	3.151	23
2.2 m	0.090	0.067	26	98.014	94.177	4	0.083	0.100	-20	6.497	6.812	-5
3.3 m	0.010	0.009	10	35.727	32.658	9	0.021	0.011	48	1.389	1.454	-5
4.4 m	0.028	0.035	-25	42.737	43.125	-1	0.039	0.016	59	1.208	1.276	-6
5.5 m	0.074	0.036	51	48.236	43.123	11	0.027	0.042	-56	1.405	1.764	-26

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

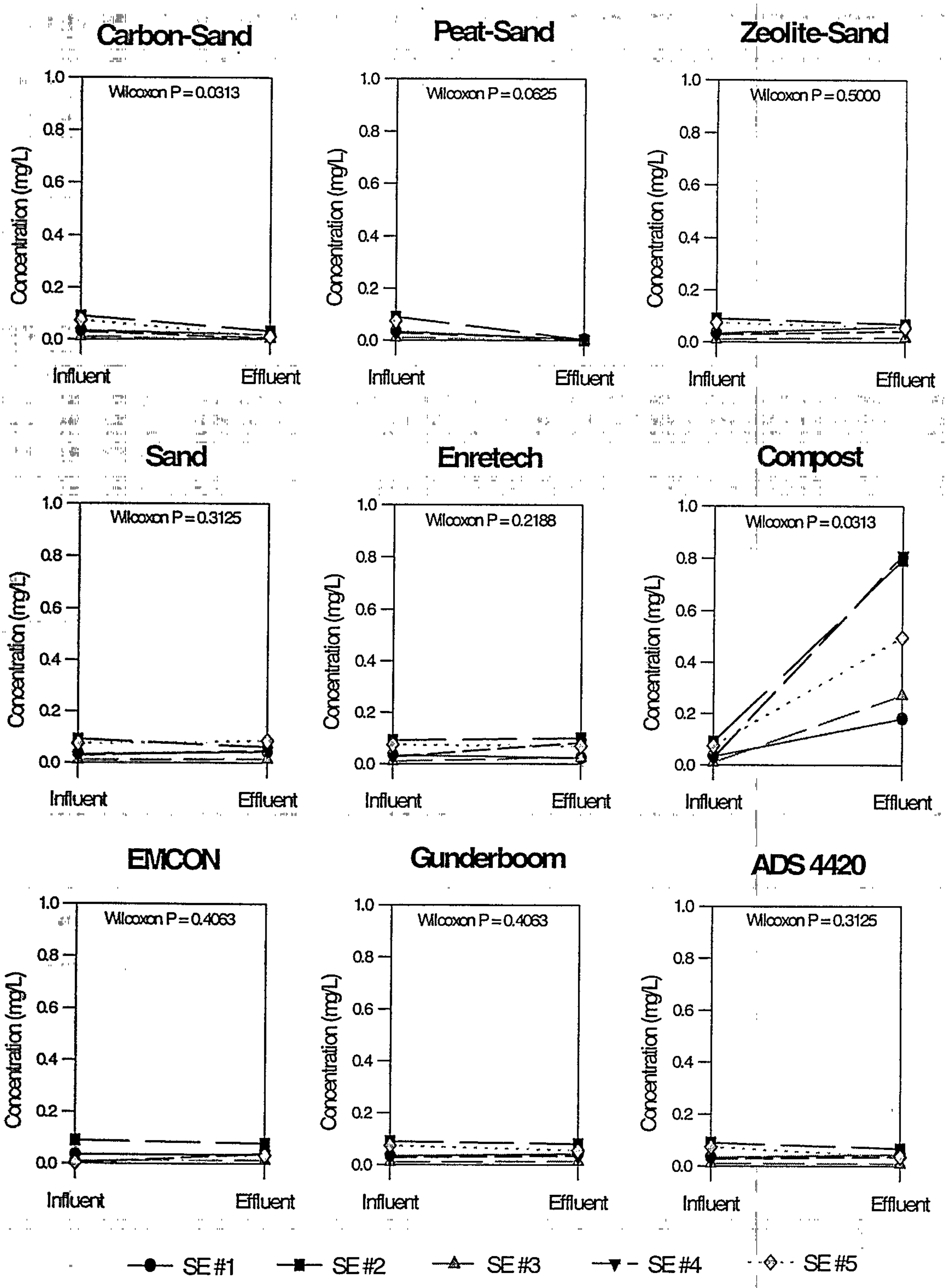
ANIONS (Continued)

SAMPLE GROUP NAME	Nitrite (mg/L)			Nitrate (mg/L)			Phosphate (mg/L)			Sulfate (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
1.1 m	ND	ND	N/A	2.028	0.238	88	3.573	0.389	89	22.620	197.885	-775
2.2 m	ND	ND	N/A	ND	ND	N/A	11.816	3.685	69	16.258	64.500	-297
3.3 m	0.053	ND	100	3.012	0.163	95	ND	ND	N/A	7.057	25.275	-258
4.4 m	ND	ND	N/A	2.776	0.077	97	ND	ND	N/A	8.290	34.476	-316
5.5 m	0.857	ND	100	2.091	0.127	94	ND	ND	N/A	14.486	37.456	-159
Peat-Sand												
1.1 m	ND	ND	N/A	2.028	ND	100	3.573	1.004	72	22.620	46.187	-104
2.2 m	ND	ND	N/A	ND	ND	N/A	11.816	7.738	35	16.258	23.992	-48
3.3 m	0.053	ND	100	3.012	3.076	-2	ND	0.631	N/A	7.057	11.346	-61
4.4 m	ND	ND	N/A	2.776	2.654	4	ND	0.712	N/A	8.290	10.110	-22
5.5 m	0.857	0.744	13	2.091	1.844	12	ND	0.572	N/A	14.486	15.427	-6
Zeolite-Sand												
1.1 m	ND	ND	N/A	2.028	7.695	-279	3.573	1.049	71	22.620	21.978	3
2.2 m	ND	ND	N/A	ND	ND	N/A	11.816	9.374	21	16.258	17.392	-7
3.3 m	0.053	0.041	23	3.012	3.266	-8	ND	ND	N/A	7.057	8.540	-21
4.4 m	ND	ND	N/A	2.776	3.133	-13	ND	ND	N/A	8.290	9.490	-14
5.5 m	0.857	0.029	97	2.091	3.004	-44	ND	ND	N/A	14.486	16.144	-11
Sand												
1.1 m	ND	ND	N/A	2.028	2.103	-4	3.573	1.018	72	22.620	21.866	3
2.2 m	ND	ND	N/A	ND	0.114	N/A	11.816	9.875	16	16.258	14.215	13
3.3 m	0.053	0.053	0	3.012	3.456	-15	ND	ND	N/A	7.057	8.529	-21
4.4 m	ND	ND	N/A	2.776	2.640	5	ND	ND	N/A	8.290	8.518	-3
5.5 m	0.857	0.951	-11	2.091	1.776	15	ND	10.032	N/A	14.486	16.328	-13
Enretech												
1.1 m	ND	ND	N/A	2.028	ND	100	3.573	ND	100	22.620	32.175	-42
2.2 m	ND	ND	N/A	ND	1.070	N/A	11.816	8.032	32	16.258	26.262	-62
3.3 m	0.053	ND	100	3.012	0.156	95	ND	ND	N/A	7.057	11.543	-64
4.4 m	ND	ND	N/A	2.776	0.076	97	ND	ND	N/A	8.290	8.943	-8
5.5 m	0.857	0.582	32	2.091	1.209	42	ND	ND	N/A	14.486	18.598	-28

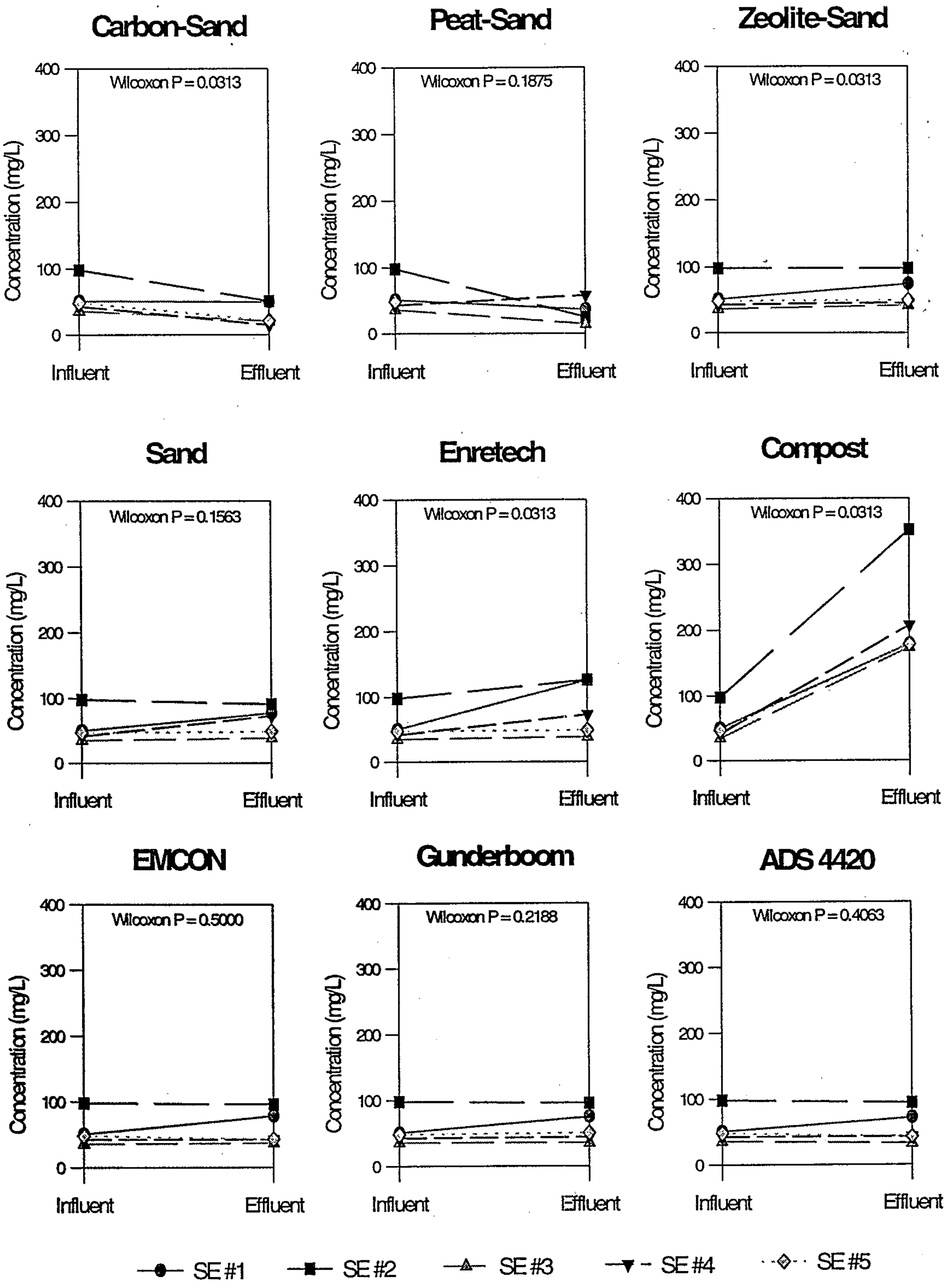
FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

ANIONS (Continued)

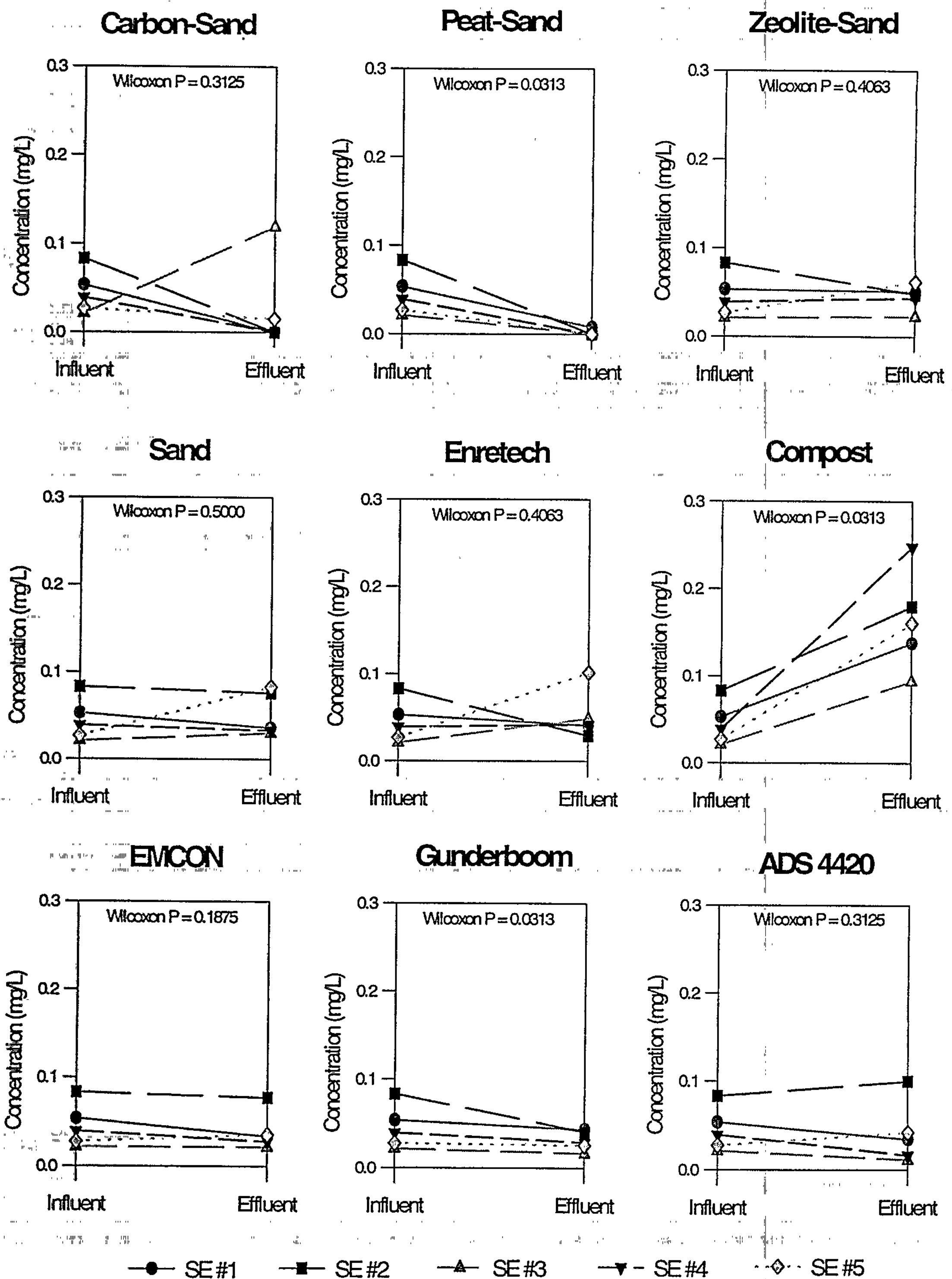
SAMPLE GROUP NAME	Nitrite (mg/L)			Nitrate (mg/L)			Phosphate (mg/L)			Sulfate (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost												
1.1 m	ND	ND	N/A	2.028	19.871	-880	3.573	2.218	38	22.620	23.345	-3
2.2 m	ND	ND	N/A	ND	3.133	N/A	11.816	9.140	23	16.258	15.771	3
3.3 m	0.053	ND	100	3.012	3.464	-15	ND	3.687	N/A	7.057	10.385	-47
4.4 m	ND	ND	N/A	2.776	3.461	-25	ND	3.995	N/A	8.290	8.521	-3
5.5 m	0.857	0.422	51	2.091	3.753	-79	ND	3.555	N/A	14.486	19.982	-38
EMCON Fabric												
1.1 m	ND	ND	N/A	2.028	2.898	-43	3.573	2.562	28	22.620	22.056	2
2.2 m	ND	ND	N/A	ND	0.129	N/A	11.816	11.040	7	16.258	14.659	10
3.3 m	0.053	0.037	30	3.012	3.478	-15	ND	ND	N/A	7.057	8.033	-14
4.4 m	ND	ND	N/A	2.776	2.661	4	ND	ND	N/A	8.290	8.266	0
5.5 m	0.857	0.728	15	2.091	1.861	11	ND	ND	N/A	14.486	14.811	-2
Gunderboom Fabric												
1.1 m	ND	ND	N/A	2.028	2.927	-44	3.573	1.573	56	22.620	19.058	16
2.2 m	ND	ND	N/A	ND	ND	N/A	11.816	9.942	16	16.258	13.170	19
3.3 m	0.053	0.056	-6	3.012	3.008	0	ND	ND	N/A	7.057	7.292	-3
4.4 m	ND	ND	N/A	2.776	2.816	-1	ND	ND	N/A	8.290	8.684	-5
5.5 m	0.857	0.854	0	2.091	1.916	8	ND	0.769	N/A	14.486	14.257	2
ADS 4420 Fabric												
1.1 m	ND	ND	N/A	2.028	2.942	-45	3.573	2.464	31	22.620	20.832	8
2.2 m	ND	ND	N/A	ND	ND	N/A	11.816	10.804	9	16.258	15.554	4
3.3 m	0.053	0.036	32	3.012	3.061	-2	ND	ND	N/A	7.057	7.250	-3
4.4 m	ND	ND	N/A	2.776	2.847	-3	ND	ND	N/A	8.290	8.400	-1
5.5 m	0.857	0.563	34	2.091	2.513	-20	ND	0.373	N/A	14.486	14.736	-2



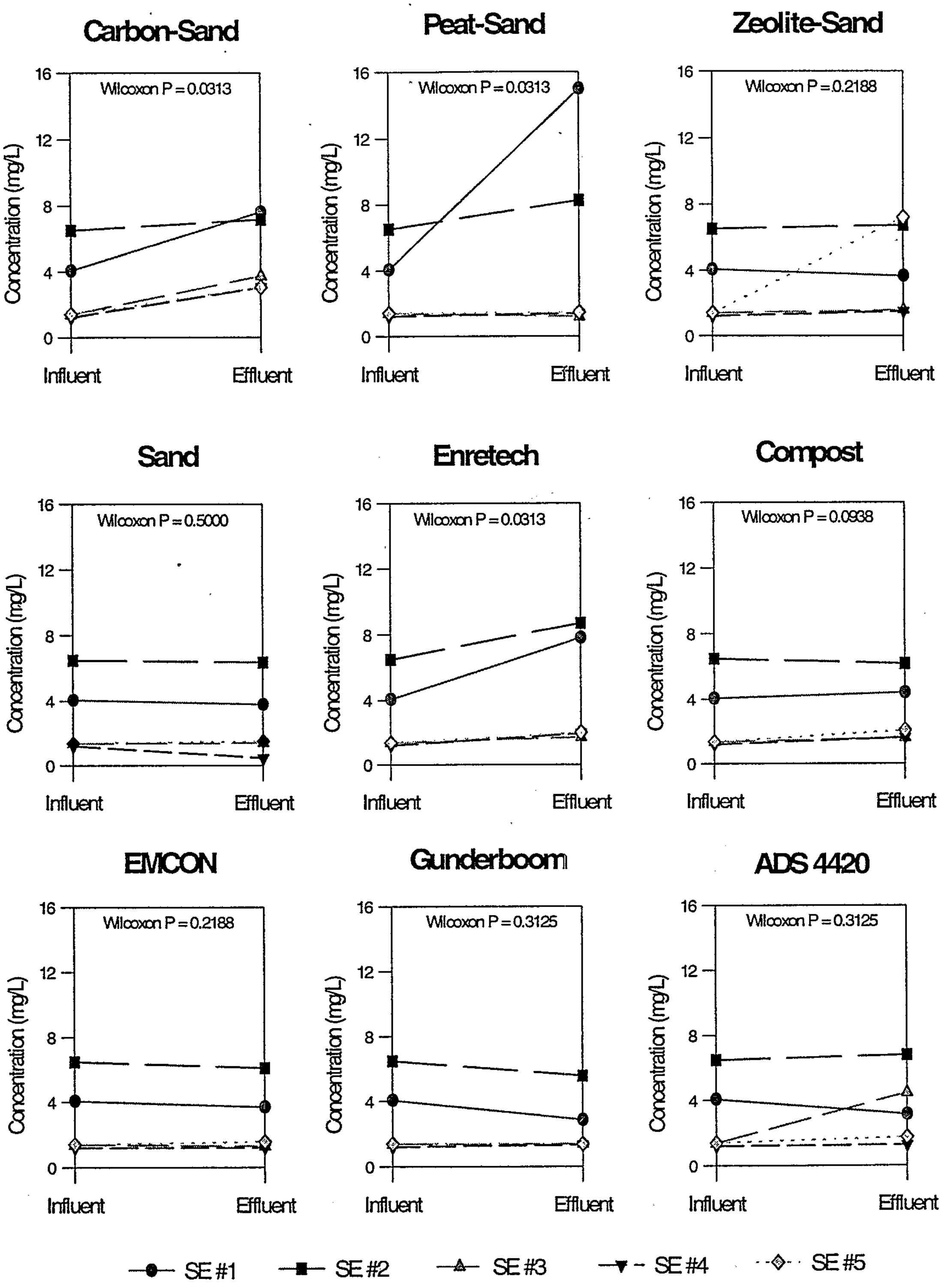
CARBONATE: Unpretreated Influent



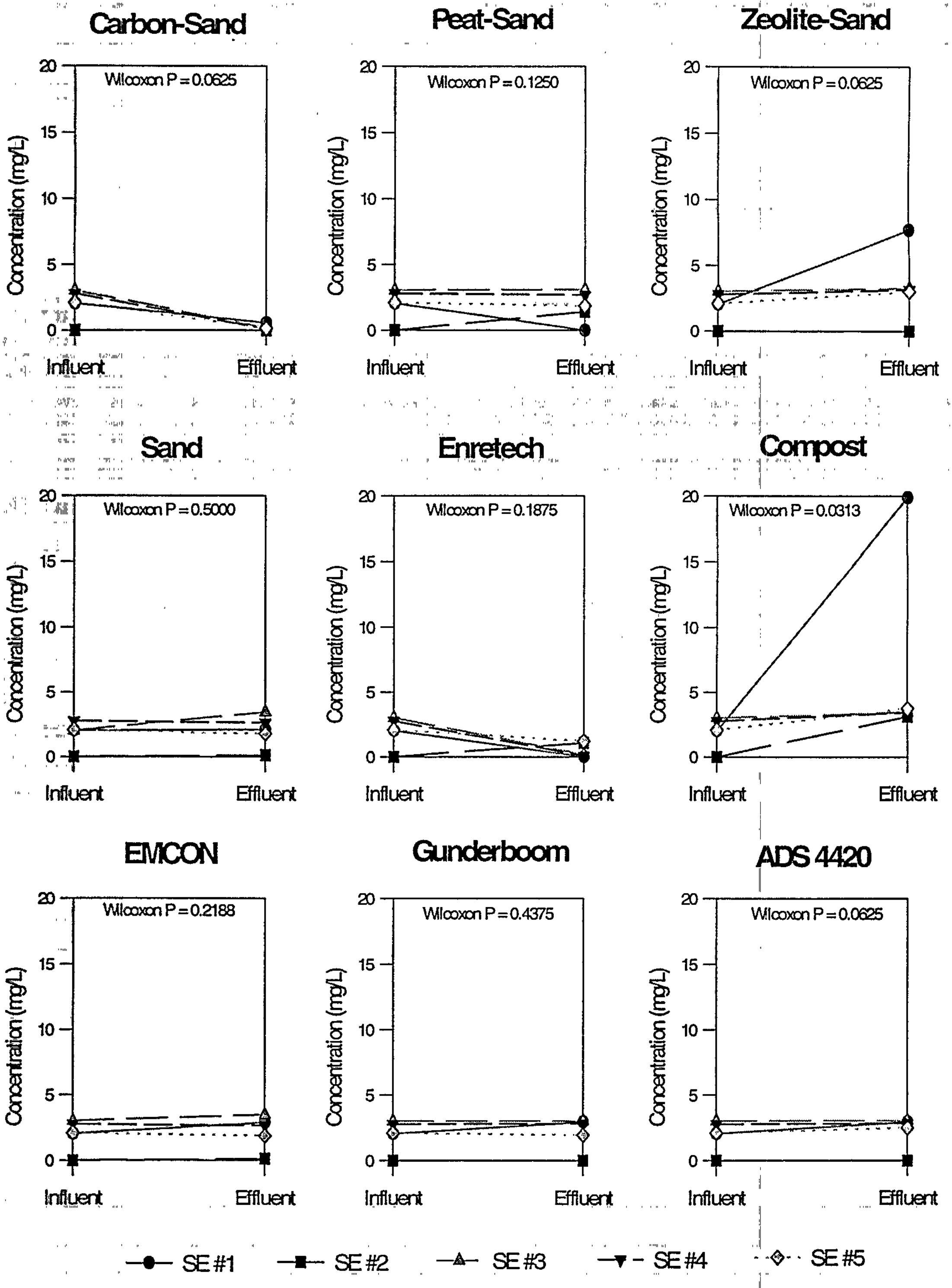
BICARBONATE: Unpretreated Influent



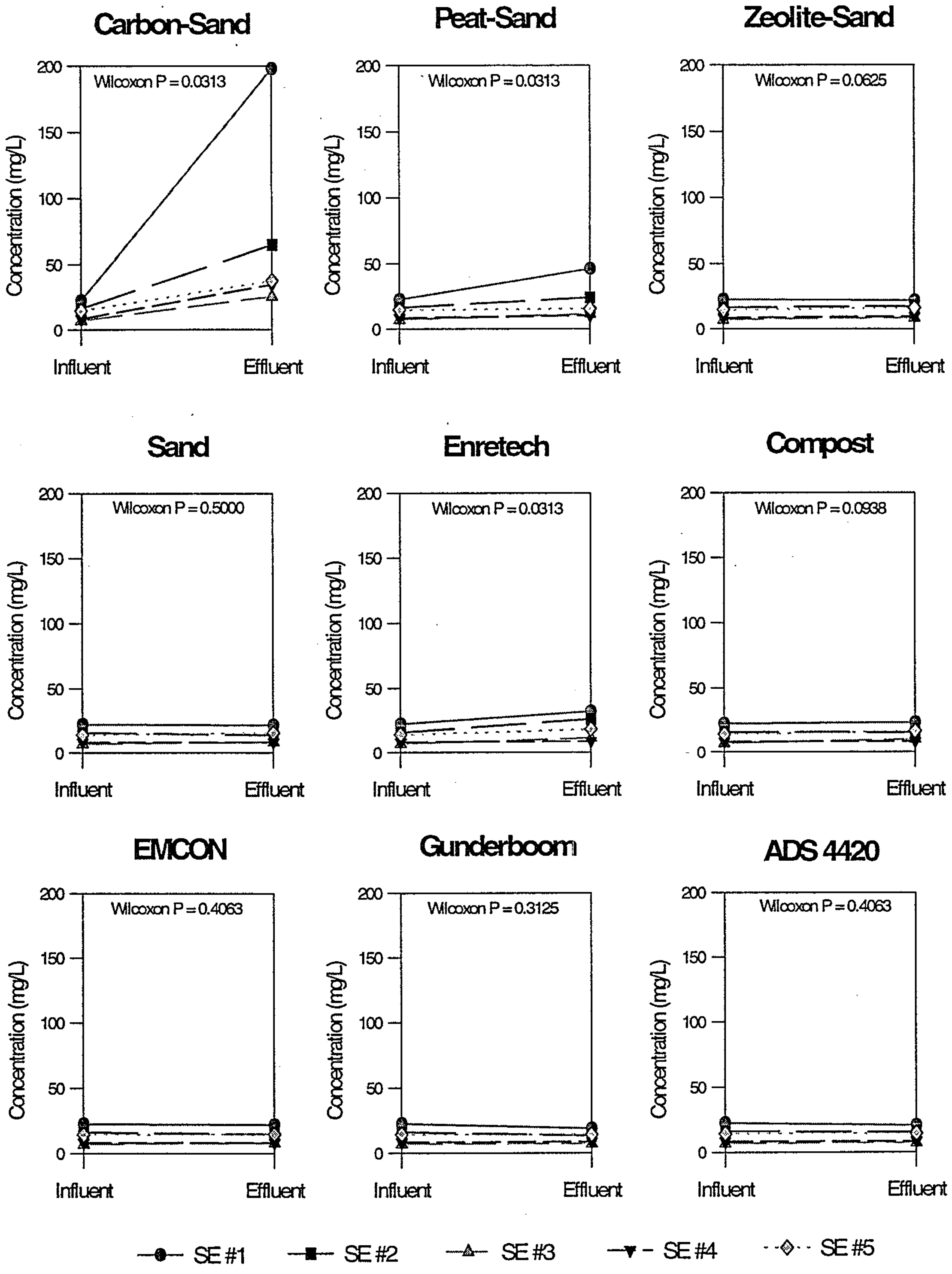
FLUORIDE: Unpretreated Influent



CHLORIDE: Unpretreated Influent



NITRATE: Unpretreated Influent



SULFATE: Unpretreated Influent

Appendix E:
Cations

Hardness
Lithium
Sodium
Ammonium
Potassium
Magnesium
Calcium

CATIONS

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Lithium (mg/L) MDL = 0.014 mg/L			Sodium (mg/L) MDL = 0.454 mg/L			Ammonium (mg/L) MDL = 0.123 mg/L			Potassium (mg/L) MDL = 0.081 mg/L		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	ND	ND	N/A	0.902	3.677	-308	0.045	ND	100	0.594	0.441	26
13.1 m	ND	ND	N/A	0.819	2.000	-144	0.238	0.063	74	0.701	0.425	39
16.4 m	ND	ND	N/A	0.861	1.170	-36	0.066	0.074	-12	0.702	0.673	4
20.6 m	ND	ND	N/A	0.965	1.285	-33	0.179	0.132	26	0.587	0.566	4
25.0 m	ND	ND	N/A	0.907	0.990	-9	0.140	0.142	-1	0.575	0.564	2
Peat-Sand												
8.5 m	ND	ND	N/A	0.902	1.409	-56	0.045	0.094	-109	0.594	1.060	-78
13.1 m	ND	ND	N/A	0.819	0.709	13	0.238	0.079	67	0.701	0.707	-1
16.4 m	ND	ND	N/A	0.861	0.657	24	0.066	0.104	-58	0.702	0.865	-23
20.6 m	ND	ND	N/A	0.965	1.026	-6	0.179	0.183	-2	0.587	0.812	-38
25.0 m	ND	ND	N/A	0.907	0.887	2	0.140	0.163	-16	0.575	0.702	-22
Zeolite-Sand												
8.5 m	ND	ND	N/A	0.902	2.677	-197	0.045	ND	100	0.594	0.461	22
13.1 m	ND	ND	N/A	0.819	1.981	-142	0.238	0.113	53	0.701	0.308	56
16.4 m	ND	ND	N/A	0.861	2.033	-136	0.066	0.101	-53	0.702	0.381	46
20.6 m	ND	ND	N/A	0.965	4.782	-396	0.179	0.185	-3	0.587	0.381	35
25.0 m	ND	ND	N/A	0.907	1.478	-63	0.140	0.126	10	0.575	0.357	38
Compost-Sand												
8.5 m	ND	ND	N/A	0.902	1.332	-48	0.045	0.677	-1404	0.594	5.402	-809
13.1 m	ND	ND	N/A	0.819	0.445	46	0.238	0.076	68	0.701	1.198	-71
16.4 m	ND	ND	N/A	0.861	0.971	-13	0.066	0.126	-91	0.702	2.054	-193
20.6 m	ND	ND	N/A	0.965	2.104	-118	0.179	0.117	35	0.587	1.285	-119
25.0 m	ND	ND	N/A	0.907	0.744	18	0.140	0.326	-133	0.575	1.242	-116
Enretech-Sand												
8.5 m	ND	ND	N/A	0.902	1.356	-50	0.045	0.049	-9	0.594	0.636	-7
13.1 m	ND	ND	N/A	0.819	1.005	-23	0.238	0.072	70	0.701	0.763	-9
16.4 m	ND	ND	N/A	0.861	0.727	16	0.066	0.088	-33	0.702	0.689	2
20.6 m	ND	ND	N/A	0.965	1.119	-16	0.179	0.117	35	0.587	0.726	-24
25.0 m	ND	ND	N/A	0.907	3.046	-236	0.140	0.600	-329	0.575	3.397	-491

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

CATIONS (Continued)

SAMPLE GROUP NAME	Lithium (mg/L) MDL = 0.014 mg/L			Sodium (mg/L) MDL = 0.454 mg/L			Ammonium (mg/L) MDL = 0.123 mg/L			Potassium (mg/L) MDL = 0.081 mg/L		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	ND	ND	N/A	0.902	1.433	-59	0.045	0.071	-58	0.594	0.713	-20
13.1 m	ND	ND	N/A	0.819	0.982	-20	0.238	0.070	71	0.701	0.800	-14
16.4 m	ND	ND	N/A	0.861	0.908	-5	0.066	0.084	-27	0.702	0.776	-11
20.6 m	ND	ND	N/A	0.965	1.027	-6	0.179	0.132	26	0.587	0.690	-18
25.0 m	ND	ND	N/A	0.907	1.133	-25	0.140	0.229	-64	0.575	0.736	-28
Sand												
8.5 m	ND	ND	N/A	0.902	1.064	-18	0.045	0.079	-76	0.594	0.558	6
13.1 m	ND	ND	N/A	0.819	1.016	-24	0.238	0.067	72	0.701	0.782	-12
16.4 m	ND	ND	N/A	0.861	0.869	-1	0.066	0.085	-29	0.702	0.686	2
20.6 m	ND	0.001	N/A	0.965	0.893	7	0.179	0.136	24	0.587	0.583	1
25.0 m	ND	ND	N/A	0.907	0.726	20	0.140	0.142	-1	0.575	0.509	11
Gunderboom Fabric												
8.5 m	ND	ND	N/A	0.902	4.188	-364	0.045	0.082	-82	0.594	0.626	-5
13.1 m	ND	ND	N/A	0.819	0.662	19	0.238	0.248	-4	0.701	0.841	-20
16.4 m	ND	ND	N/A	0.861	0.715	17	0.066	0.116	-76	0.702	0.684	3
20.6 m	ND	ND	N/A	0.965	1.037	-7	0.179	0.143	20	0.587	0.608	-4
25.0 m	ND	ND	N/A	0.907	0.955	-5	0.140	0.155	-11	0.575	0.524	9
EMCON Fabric												
8.5 m	ND	ND	N/A	0.902	2.215	-146	0.045	0.067	-49	0.594	0.617	-4
13.1 m	ND	ND	N/A	0.819	0.755	8	0.238	0.141	41	0.701	0.759	-8
16.4 m	ND	ND	N/A	0.861	0.782	9	0.066	0.087	-32	0.702	0.734	-5
20.6 m	ND	ND	N/A	0.965	0.755	22	0.179	0.082	54	0.587	0.518	12
25.0 m	ND	ND	N/A	0.907	1.000	-10	0.140	0.131	6	0.575	0.600	-4

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall, 1995

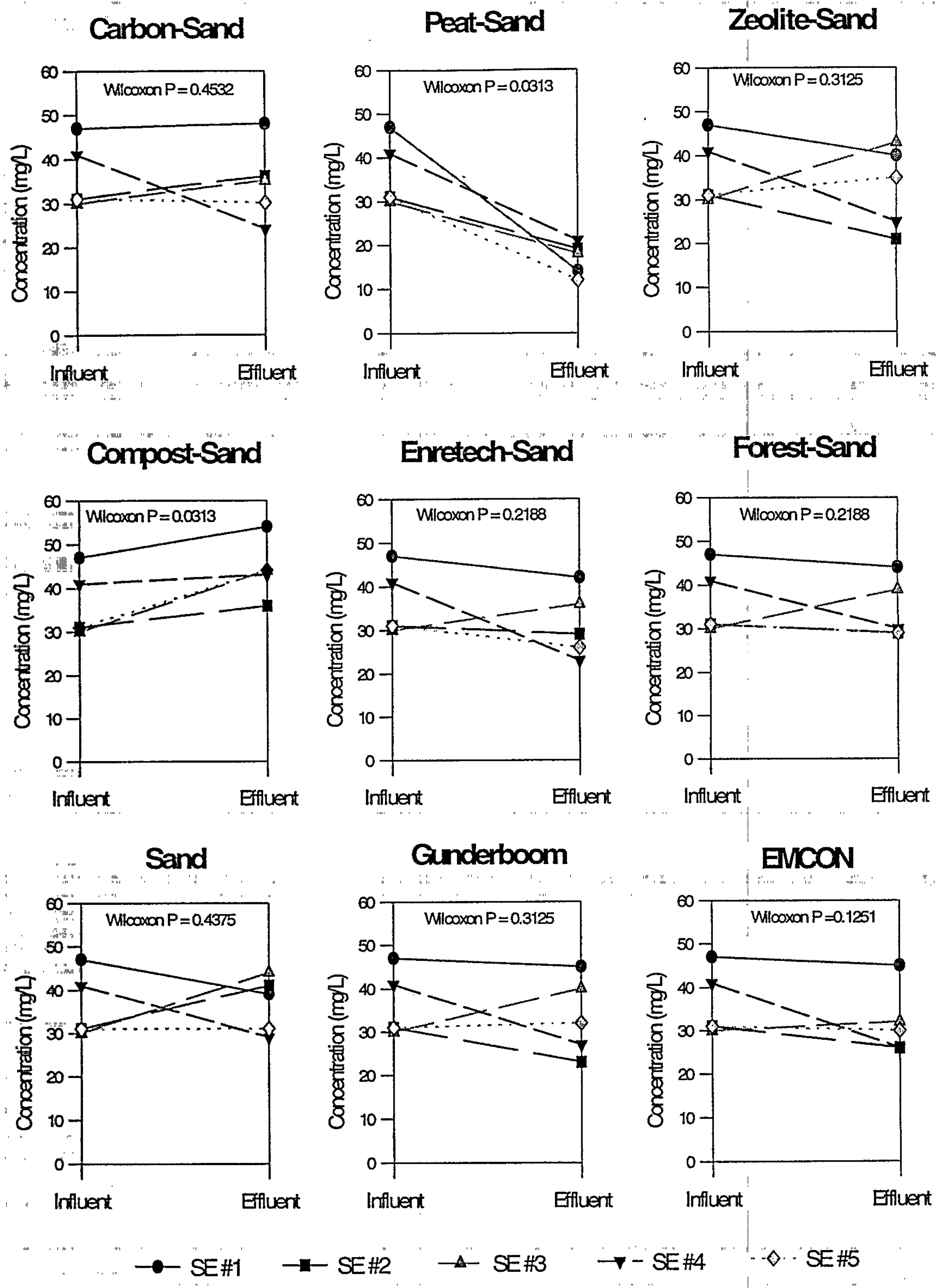
CATIONS (Continued)

SAMPLE GROUP NAME	Magnesium (mg/L) MDL = 0.055 mg/L			Calcium MDL = 0.318 mg/L			Total Hardness (mg/L as $CaCO_3$)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
8.5 m	1.401	1.383	1	10.756	9.724	10	47	48	-2
13.1 m	0.608	1.006	-65	5.872	6.664	-13	31	36	-16
16.4 m	0.968	0.945	2	8.071	7.419	8	30	35	-17
20.6 m	0.806	0.824	-2	6.757	6.487	4	41	24	41
25.0 m	0.975	0.931	5	7.046	6.822	3	31	30	3
Peat-Sand									
8.5 m	1.401	0.596	57	10.756	0.929	91	47	14	70
13.1 m	0.608	0.595	2	5.872	0.833	86	31	19	39
16.4 m	0.968	0.587	39	8.071	0.944	88	30	18	40
20.6 m	0.806	0.961	-19	6.757	0.958	86	41	21	49
25.0 m	0.975	1.126	-15	7.046	0.773	89	31	12	61
Zeolite-Sand									
8.5 m	1.401	1.463	-4	10.756	9.591	11	47	40	15
13.1 m	0.608	0.853	-40	5.872	5.164	12	31	21	32
16.4 m	0.968	1.064	-10	8.071	6.447	20	30	43	-43
20.6 m	0.806	0.661	18	6.757	4.598	32	41	25	39
25.0 m	0.975	1.021	-5	7.046	6.475	8	31	35	-13
Compost-Sand									
8.5 m	1.401	2.512	-79	10.756	12.125	-13	47	54	-15
13.1 m	0.608	0.894	-47	5.872	4.250	28	31	36	-16
16.4 m	0.968	1.826	-89	8.071	9.053	-12	30	44	-47
20.6 m	0.806	1.729	-115	6.757	8.558	-27	41	43	-5
25.0 m	0.975	1.811	-86	7.046	8.993	-28	31	44	-42
Enretech-Sand									
8.5 m	1.401	1.364	3	10.756	10.610	1	47	42	11
13.1 m	0.608	0.755	-24	5.872	5.999	-2	31	29	6
16.4 m	0.968	0.980	-1	8.071	8.374	-4	30	36	-20
20.6 m	0.806	0.854	-6	6.757	7.120	-5	41	23	44
25.0 m	0.975	0.997	-2	7.046	7.134	-1	31	26	16

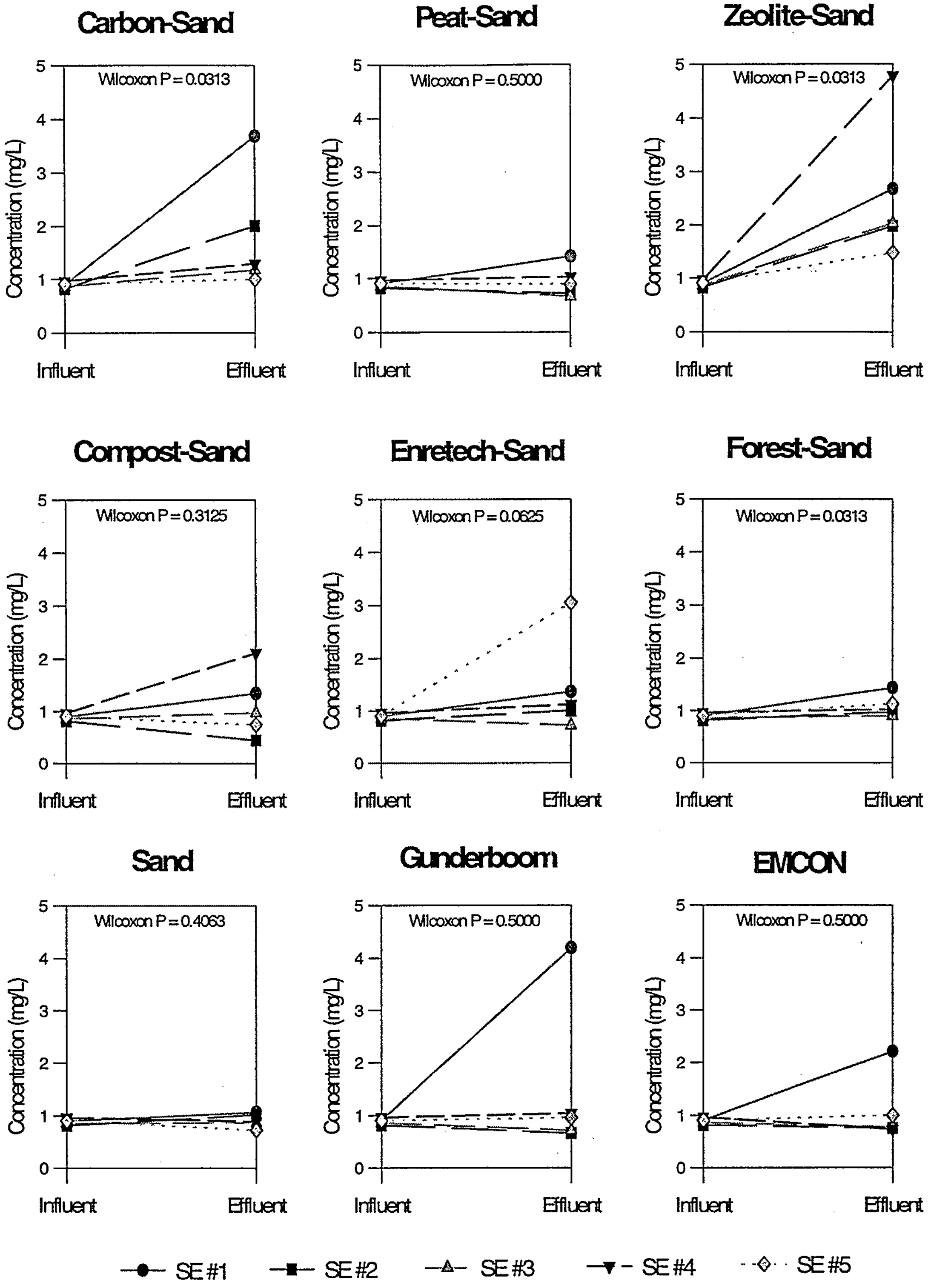
FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall, 1995

CATIONS (Continued)

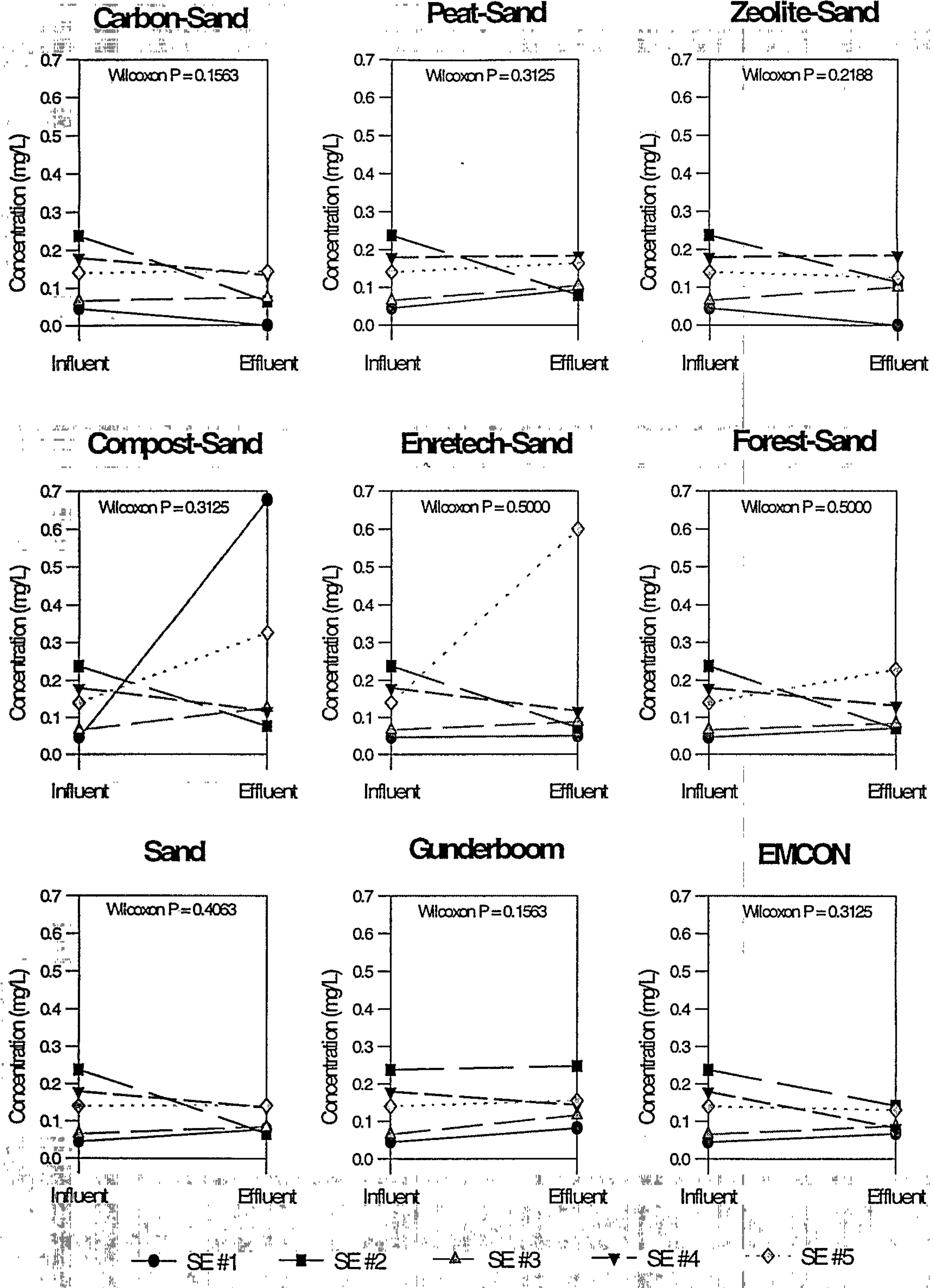
SAMPLE GROUP NAME	Magnesium (mg/L) MDL = 0.055 mg/L			Calcium MDL = 0.318 mg/L			Total Hardness (mg/L as $CaCO_3$)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand									
8.5 m	1.401	1.329	5	10.756	10.170	5	47	44	6
13.1 m	0.608	0.841	-38	5.872	6.241	-6	31	29	6
16.4 m	0.968	1.004	-4	8.071	8.254	-2	30	39	-30
20.6 m	0.806	0.864	-7	6.757	7.019	-4	41	30	27
25.0 m	0.975	0.900	8	7.046	6.473	8	31	29	6
Sand									
8.5 m	1.401	1.378	2	10.756	10.807	0	47	39	17
13.1 m	0.608	0.754	-24	5.872	6.289	-7	31	41	-32
16.4 m	0.968	0.962	1	8.071	8.038	0	30	44	-47
20.6 m	0.806	0.799	1	6.757	6.890	-2	41	29	29
25.0 m	0.975	0.992	-2	7.046	7.284	-3	31	31	0
Gunderboom Fabric									
8.5 m	1.401	1.442	-3	10.756	11.142	-4	47	45	4
13.1 m	0.608	0.735	-21	5.872	7.455	-27	31	23	26
16.4 m	0.968	0.941	3	8.071	7.882	2	30	40	-33
20.6 m	0.806	0.854	-6	6.757	7.222	-7	41	27	34
25.0 m	0.975	0.959	2	7.046	7.048	0	31	32	-3
EMCON Fabric									
8.5 m	1.401	1.412	-1	10.756	10.608	1	47	45	4
13.1 m	0.608	0.598	2	5.872	5.863	0	31	26	16
16.4 m	0.968	0.948	2	8.071	7.849	3	30	32	-7
20.6 m	0.806	0.850	-5	6.757	6.999	-4	41	26	37
25.0 m	0.975	0.946	3	7.046	6.850	3	31	30	3



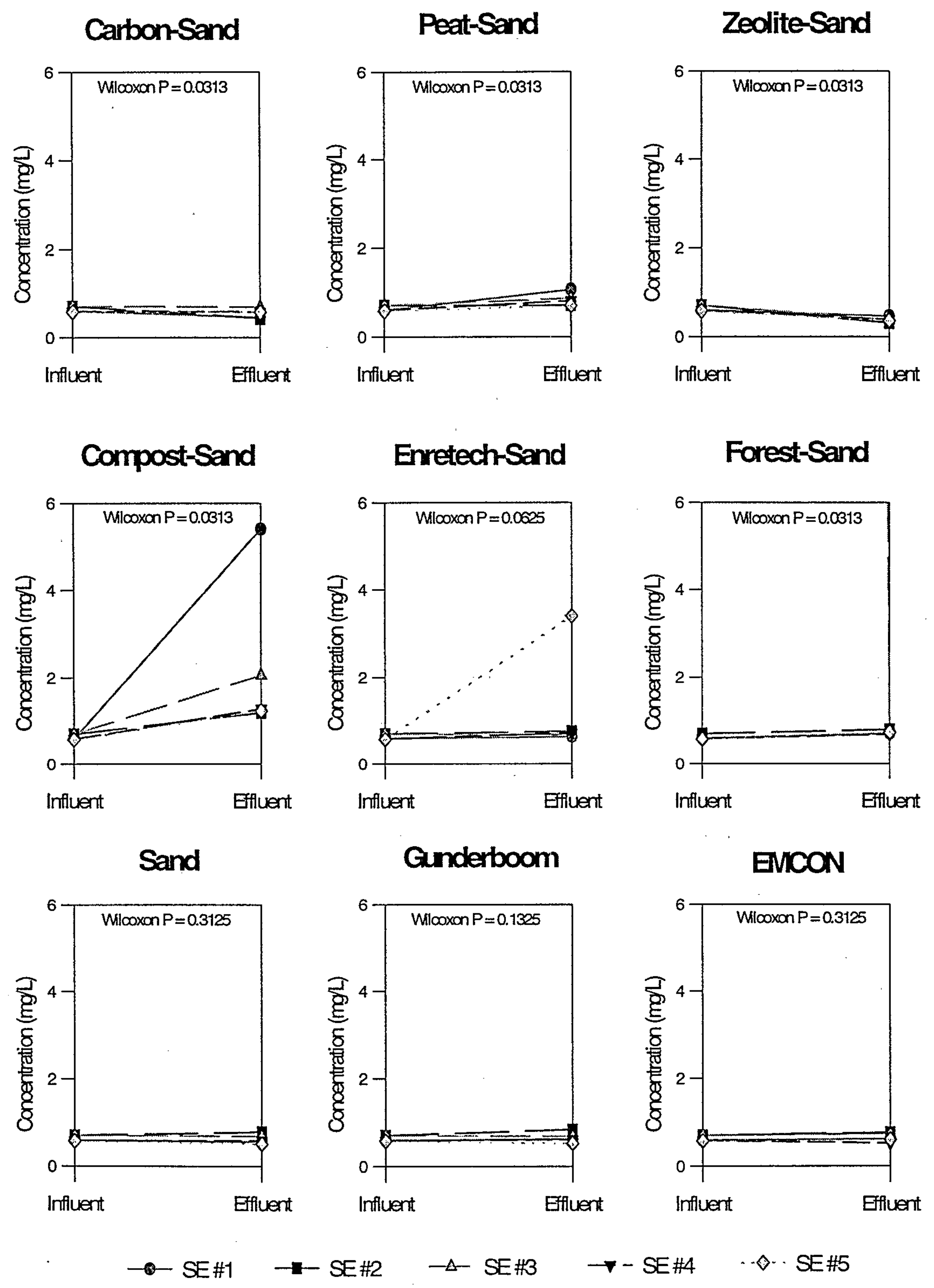
HARDNESS: Pre-Settled Influent



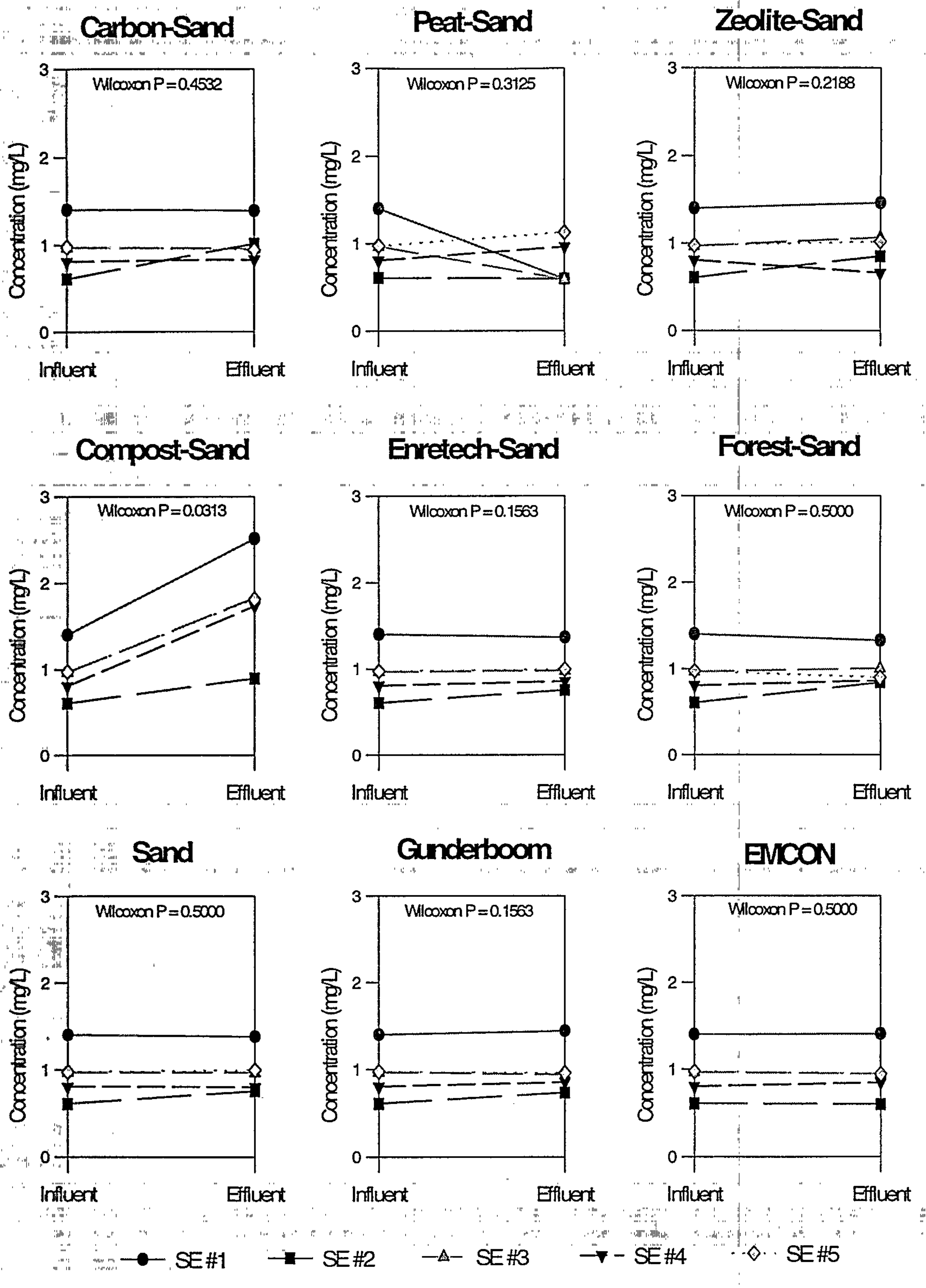
SODIUM: Pre-Settled Influent



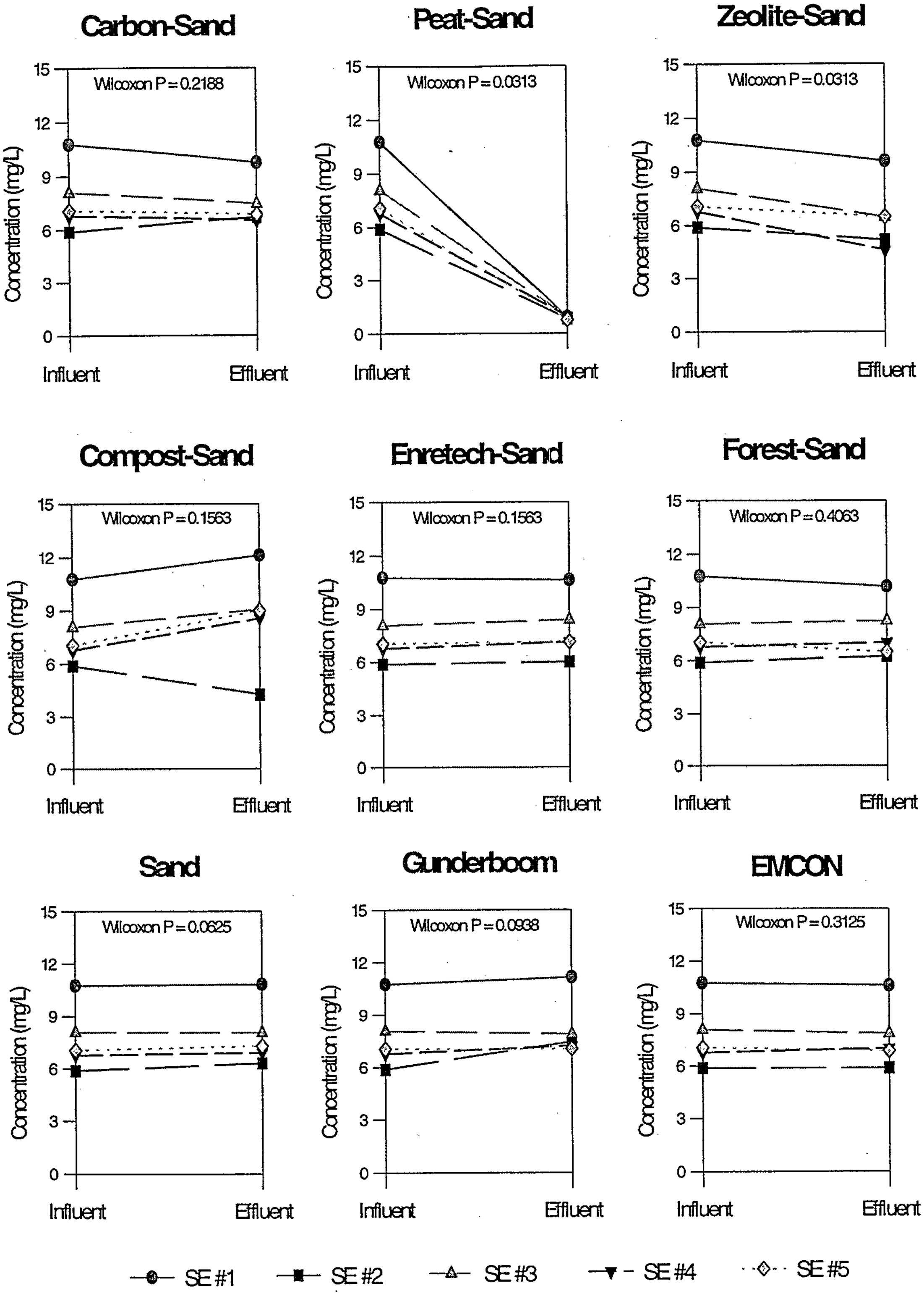
AMMONIUM: Pre-Settled Influent



POTASSIUM: Pre-Settled Influent



MAGNESIUM: Pre-Settled Influent



CALCIUM: Pre-Settled Influent

CATIONS

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Lithium (mg/L)			Sodium (mg/L)			Ammonium (mg/L)			Potassium (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
1.1 m	0.003	0.017	-467	8.999	69.320	-670	1.035	nd	100	1.951	0.683	65
2.2 m	0.002	0.005	-150	16.185	28.270	-75	nd	nd	N/A	1.810	0.610	66
3.3 m	ND	0.004	N/A	1.350	6.098	-352	0.236	0.669	-183	0.636	0.547	14
4.4 m	ND	ND	N/A	1.002	4.685	-368	0.042	nd	100	0.642	0.351	45
5.5 m	ND	ND	N/A	1.527	3.359	-120	0.130	0.182	-40	0.852	0.517	39
Peat-Sand												
1.1 m	0.003	0.002	33	8.999	10.266	-14	1.035	nd	100	1.951	24.387	-1150
2.2 m	0.002	0.001	50	16.185	11.723	28	nd	nd	N/A	1.810	9.580	-429
3.3 m	ND	ND	N/A	1.350	5.944	-340	0.236	0.964	-308	0.636	4.757	-648
4.4 m	ND	ND	N/A	1.002	3.734	-273	0.042	nd	100	0.642	4.899	-663
5.5 m	ND	ND	N/A	1.527	1.958	-28	0.130	0.117	10	0.852	2.200	-158
Zeolite-Sand												
1.1 m	0.003	0.004	-33	8.999	7.424	18	1.035	nd	100	1.951	1.424	27
2.2 m	0.002	0.002	0	16.185	11.955	26	nd	nd	N/A	1.810	1.101	39
3.3 m	ND	ND	N/A	1.350	2.720	-101	0.236	0.531	-125	0.636	0.495	22
4.4 m	ND	ND	N/A	1.002	2.271	-127	0.042	0.155	-269	0.642	0.326	49
5.5 m	ND	ND	N/A	1.527	3.093	-103	0.130	nd	100	0.852	0.519	39
Sand												
1.1 m	0.003	0.001	67	8.999	6.765	25	1.035	0.611	41	1.951	1.477	24
2.2 m	0.002	0.001	50	16.185	14.433	11	nd	nd	N/A	1.810	1.626	10
3.3 m	ND	ND	N/A	1.350	1.566	-16	0.236	0.335	-42	0.636	0.679	-7
4.4 m	ND	ND	N/A	1.002	1.083	-8	0.042	0.043	-2	0.642	0.687	-7
5.5 m	ND	ND	N/A	1.527	1.594	-4	0.130	0.751	-478	0.852	0.896	-5
Enretech												
1.1 m	0.003	0.003	0	8.999	19.613	-118	1.035	nd	100	1.951	2.449	-26
2.2 m	0.002	0.001	50	16.185	>20.000	N/A	nd	nd	N/A	1.810	1.601	12
3.3 m	ND	0.002	N/A	1.350	8.059	-497	0.236	nd	100	0.636	1.269	-100
4.4 m	ND	0.002	N/A	1.002	3.224	-222	0.042	nd	100	0.642	0.797	-24
5.5 m	ND	ND	N/A	1.527	2.480	-62	0.130	nd	100	0.852	0.913	-7

CATIONS (Continued)

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Lithium (mg/L)			Sodium (mg/L)			Ammonium (mg/L)			Potassium (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost												
1.1 m	0.003	ND	100	8.999	4.438	51	1.035	0.337	67	1.951	29.811	-1428
2.2 m	0.002	ND	100	16.185	9.211	43	nd	0.884	N/A	1.810	26.417	-1360
3.3 m	ND	ND	N/A	1.350	5.807	-330	0.236	0.917	-289	0.636	14.678	-2208
4.4 m	ND	ND	N/A	1.002	4.515	-351	0.042	0.630	-1400	0.642	15.930	-2381
5.5 m	ND	ND	N/A	1.527	2.654	-74	0.130	0.428	-229	0.852	10.358	-1116
EMCON Fabric												
1.1 m	0.003	0.002	33	8.999	5.939	34	1.035	0.588	43	1.951	1.339	31
2.2 m	0.002	0.002	0	16.185	14.321	12	nd	nd	N/A	1.810	1.359	25
3.3 m	ND	ND	N/A	1.350	1.068	21	0.236	0.352	-49	0.636	0.662	-4
4.4 m	ND	ND	N/A	1.002	1.119	-12	0.042	nd	100	0.642	0.625	3
5.5 m	ND	ND	N/A	1.527	1.470	4	0.130	0.051	61	0.852	0.907	-6
Gunderboom Fabric												
1.1 m	0.003	0.003	0	8.999	5.023	44	1.035	0.511	51	1.951	1.294	34
2.2 m	0.002	0.002	0	16.185	13.595	16	nd	nd	N/A	1.810	1.401	23
3.3 m	ND	0.001	N/A	1.350	0.974	28	0.236	0.284	-20	0.636	0.568	11
4.4 m	ND	0.001	N/A	1.002	1.091	-9	0.042	0.084	-100	0.642	0.653	-2
5.5 m	ND	ND	N/A	1.527	1.539	-1	0.130	0.134	-3	0.852	0.867	-2
ADS 4420 Fabric												
1.1 m	0.003	0.003	0	8.999	6.115	32	1.035	0.743	28	1.951	1.471	25
2.2 m	0.002	0.001	50	16.185	15.299	5	nd	nd	N/A	1.810	1.604	11
3.3 m	ND	ND	N/A	1.350	1.022	24	0.236	0.342	-45	0.636	0.702	-10
4.4 m	ND	ND	N/A	1.002	1.048	-5	0.042	0.075	-79	0.642	0.613	5
5.5 m	ND	ND	N/A	1.527	1.467	4	0.130	0.058	55	0.852	0.886	-4

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

CATIONS (Continued)

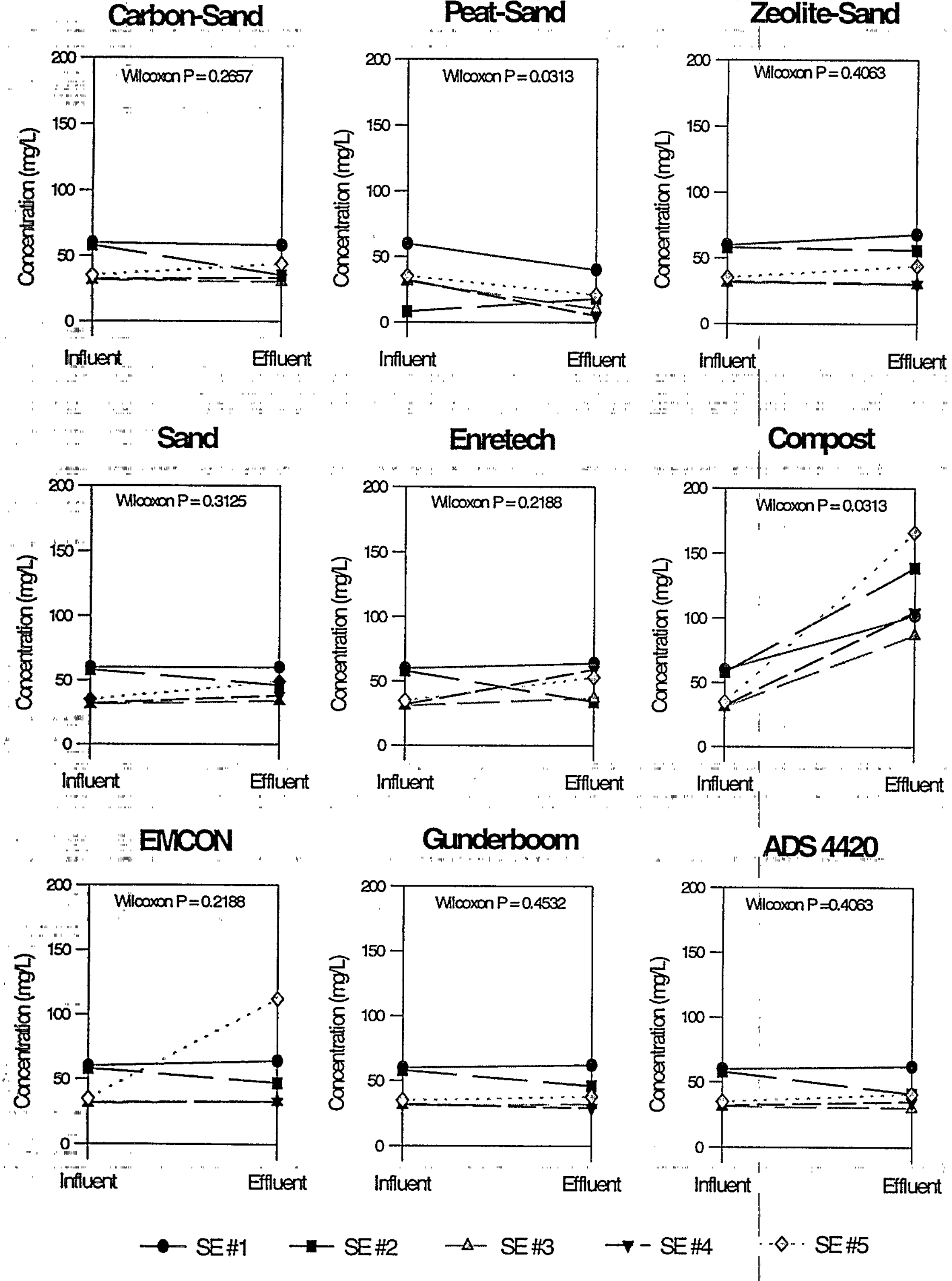
SAMPLE GROUP NAME	Magnesium (mg/L)			Calcium (mg/L)			Hardness (mg/L as $CaCO_3$)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
1.1 m	2.203	2.113	4	15.157	12.671	16	60	58	3
2.2 m	1.736	1.462	16	9.327	7.410	21	58	35	40
3.3 m	1.179	1.447	-23	6.610	6.847	-4	31	30	3
4.4 m	1.310	1.506	-15	8.032	7.577	6	32	33	-3
5.5 m	1.383	1.990	-44	10.508	11.310	-8	35	44	-26
Peat-Sand									
1.1 m	2.203	3.496	-59	15.157	6.980	54	60	40	33
2.2 m	1.736	1.109	36	9.327	2.223	76	58	18	69
3.3 m	1.179	0.378	68	6.610	0.958	86	31	10	68
4.4 m	1.310	0.492	62	8.032	1.289	84	32	5	84
5.5 m	1.383	1.409	-2	10.508	2.604	75	35	21	40
Zeolite-Sand									
1.1 m	2.203	2.656	-21	15.157	16.493	-9	60	68	-13
2.2 m	1.736	1.737	0	9.327	10.910	-17	58	56	3
3.3 m	1.179	1.197	-2	6.610	6.726	-2	31	30	3
4.4 m	1.310	1.259	4	8.032	7.548	6	32	30	6
5.5 m	1.383	1.804	-30	10.508	11.079	-5	35	44	-26
Sand									
1.1 m	2.203	2.001	9	15.157	13.555	11	60	60	0
2.2 m	1.736	1.616	7	9.327	9.294	0	58	46	21
3.3 m	1.179	1.266	-7	6.610	7.283	-10	31	34	-10
4.4 m	1.310	1.376	-5	8.032	8.652	-8	32	38	-19
5.5 m	1.383	2.755	-99	10.508	12.643	-20	35	49	-40
Enretech									
1.1 m	2.203	2.044	7	15.157	15.561	-3	60	64	-7
2.2 m	1.736	1.150	34	9.327	9.640	-3	58	34	41
3.3 m	1.179	1.072	9	6.610	8.565	-30	31	37	-19
4.4 m	1.310	1.190	9	8.032	11.325	-41	32	51	-59
5.5 m	1.383	1.715	-24	10.508	15.657	-49	35	53	-51

FILTRATION MEDIA EVALUATION: Unpretreated Influent

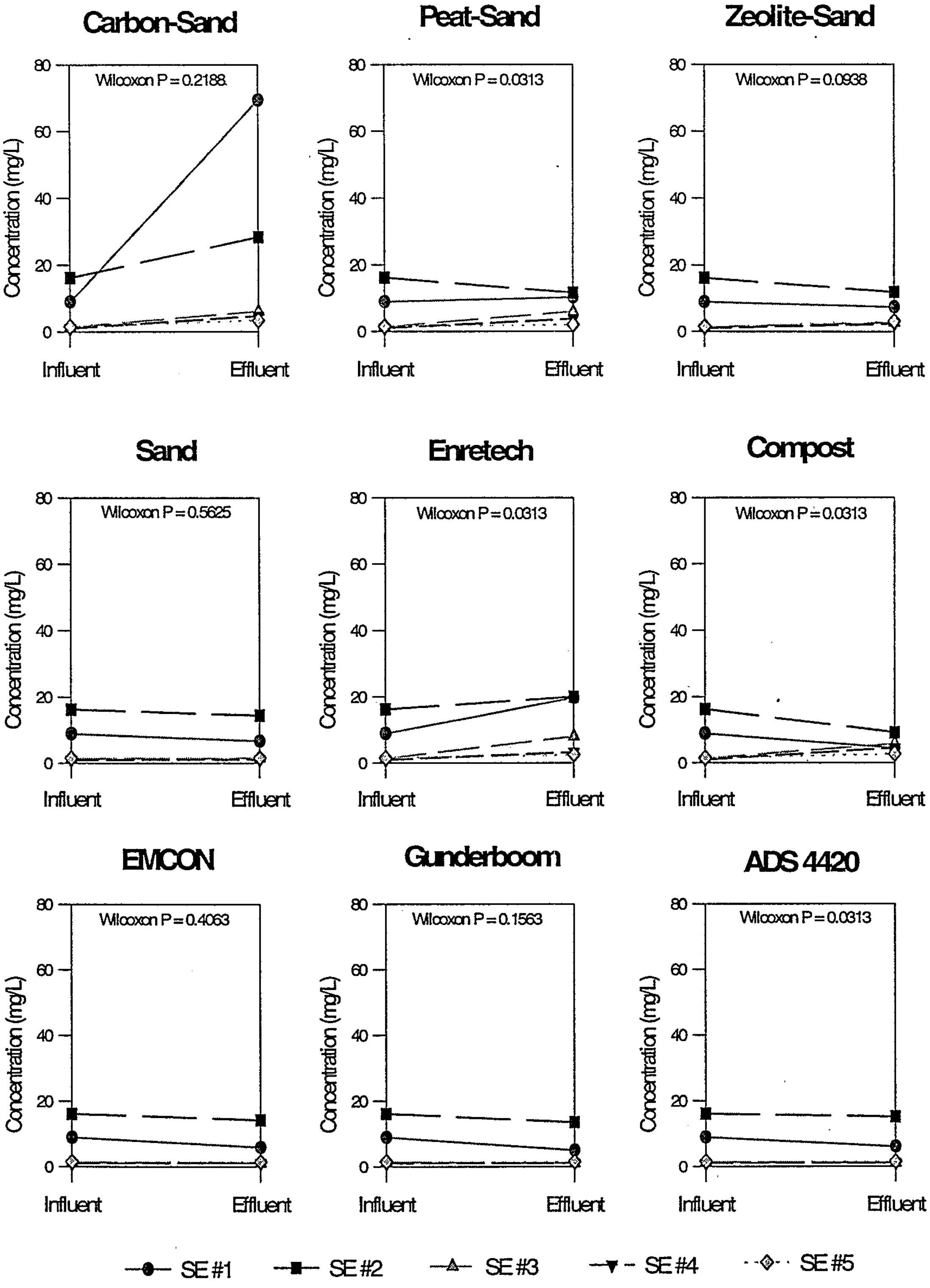
Summer 1994

CATIONS (Continued)

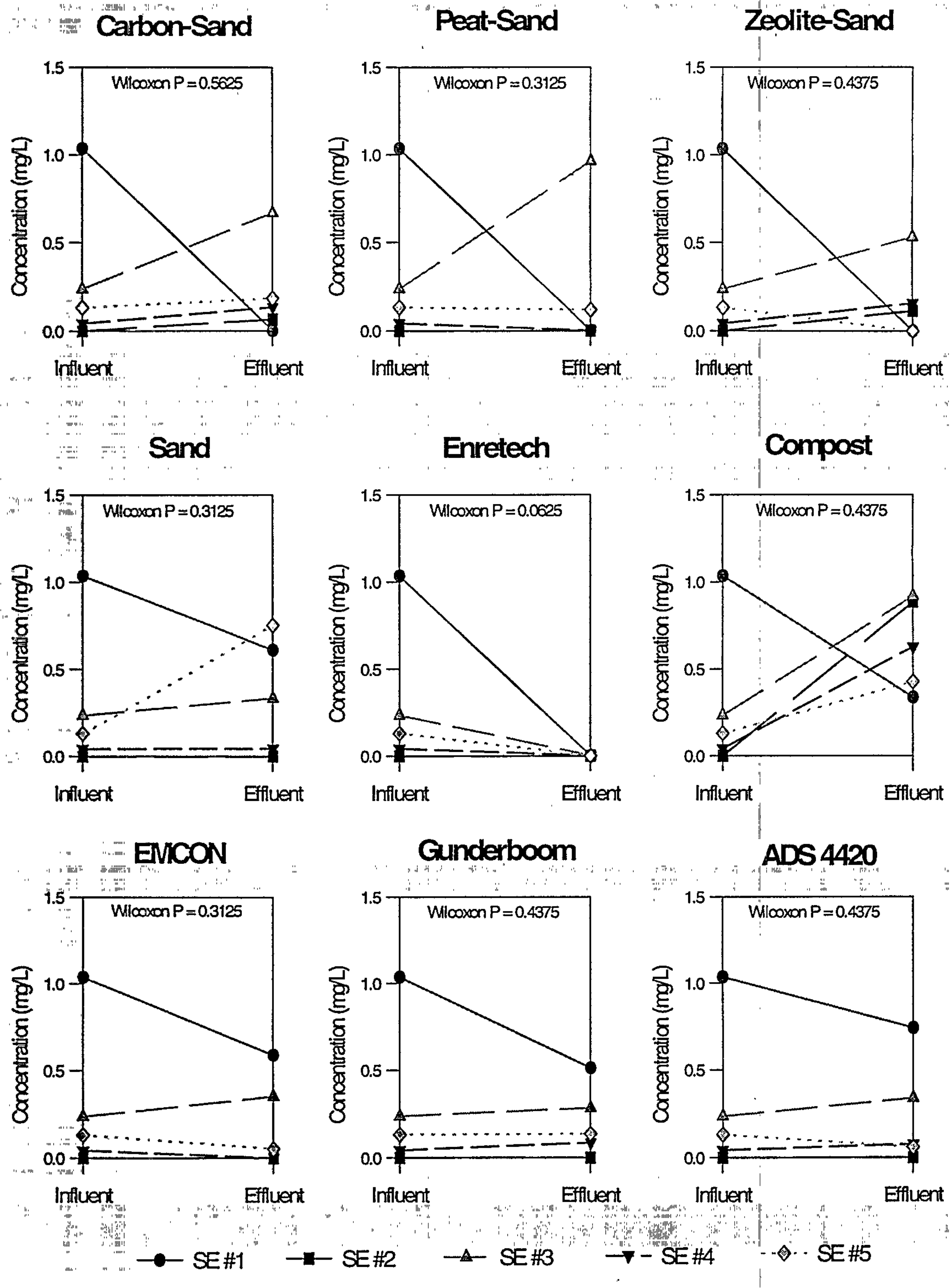
SAMPLE GROUP NAME	Magnesium (mg/L)			Calcium (mg/L)			Hardness (mg/L as $CaCO_3$)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost									
1.1 m	2.203	5.463	-148	15.157	22.900	-51	60	102	-70
2.2 m	1.736	7.010	-304	9.327	30.653	-229	58	139	-140
3.3 m	1.179	4.146	-252	6.610	18.512	-180	31	87	-181
4.4 m	1.310	5.620	-329	8.032	25.854	-222	32	105	-228
5.5 m	1.383	5.867	-324	10.508	28.667	-173	35	166	-374
EMCON Fabric									
1.1 m	2.203	1.906	13	15.157	13.659	10	60	64	-7
2.2 m	1.736	1.581	9	9.327	9.220	1	58	47	19
3.3 m	1.179	1.251	-6	6.610	6.985	-6	31	33	-6
4.4 m	1.310	1.379	-5	8.032	8.762	-9	32	33	-3
5.5 m	1.383	1.491	-8	10.508	11.488	-9	35	112	-220
Gunderboom Fabric									
1.1 m	2.203	1.997	9	15.157	14.335	5	60	62	-3
2.2 m	1.736	1.465	16	9.327	8.363	10	58	46	21
3.3 m	1.179	1.147	3	6.610	6.535	1	31	32	-3
4.4 m	1.310	1.396	-7	8.032	8.809	-10	32	29	9
5.5 m	1.383	1.348	3	10.508	9.897	6	35	38	-9
ADS 4420 Fabric									
1.1 m	2.203	2.115	4	15.157	15.232	0	60	62	-3
2.2 m	1.736	1.659	4	9.327	9.499	-2	58	47	19
3.3 m	1.179	1.269	-8	6.610	7.371	-12	31	30	3
4.4 m	1.310	1.330	-2	8.032	8.205	-2	32	35	-9
5.5 m	1.383	1.458	-5	10.508	10.919	-4	35	41	-17



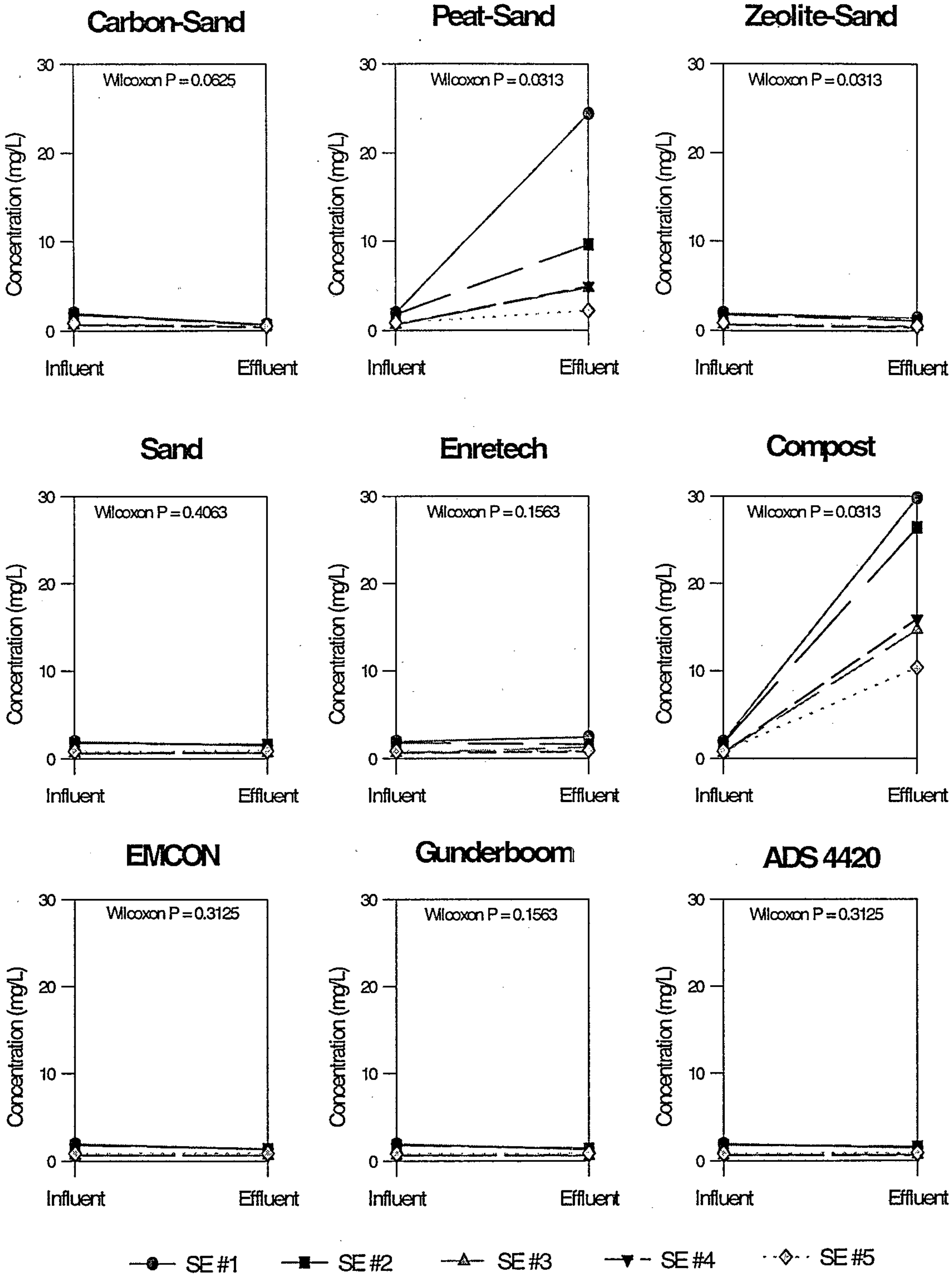
HARDNESS: Unpretreated Influent



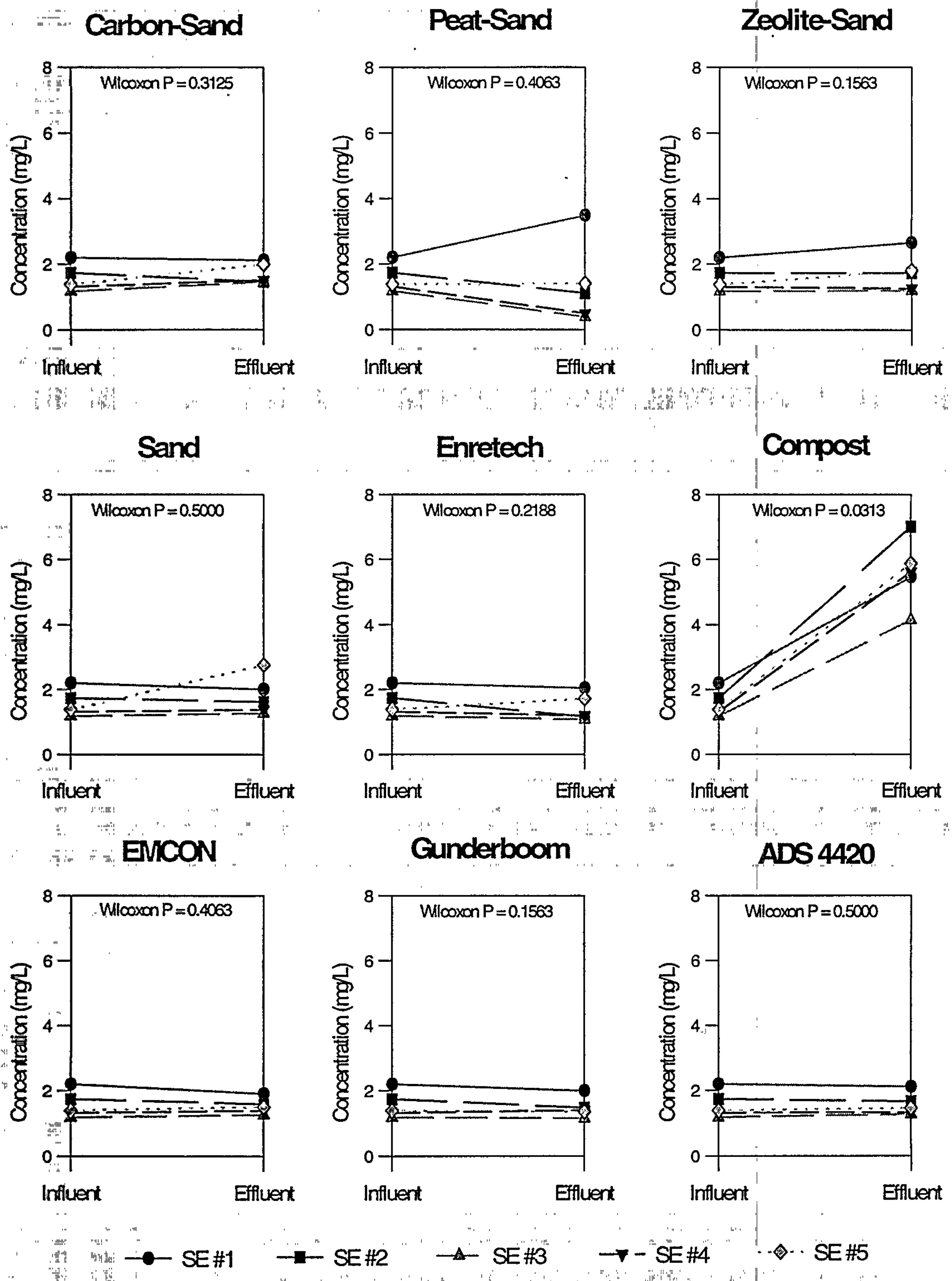
SODIUM: Unpretreated Influent



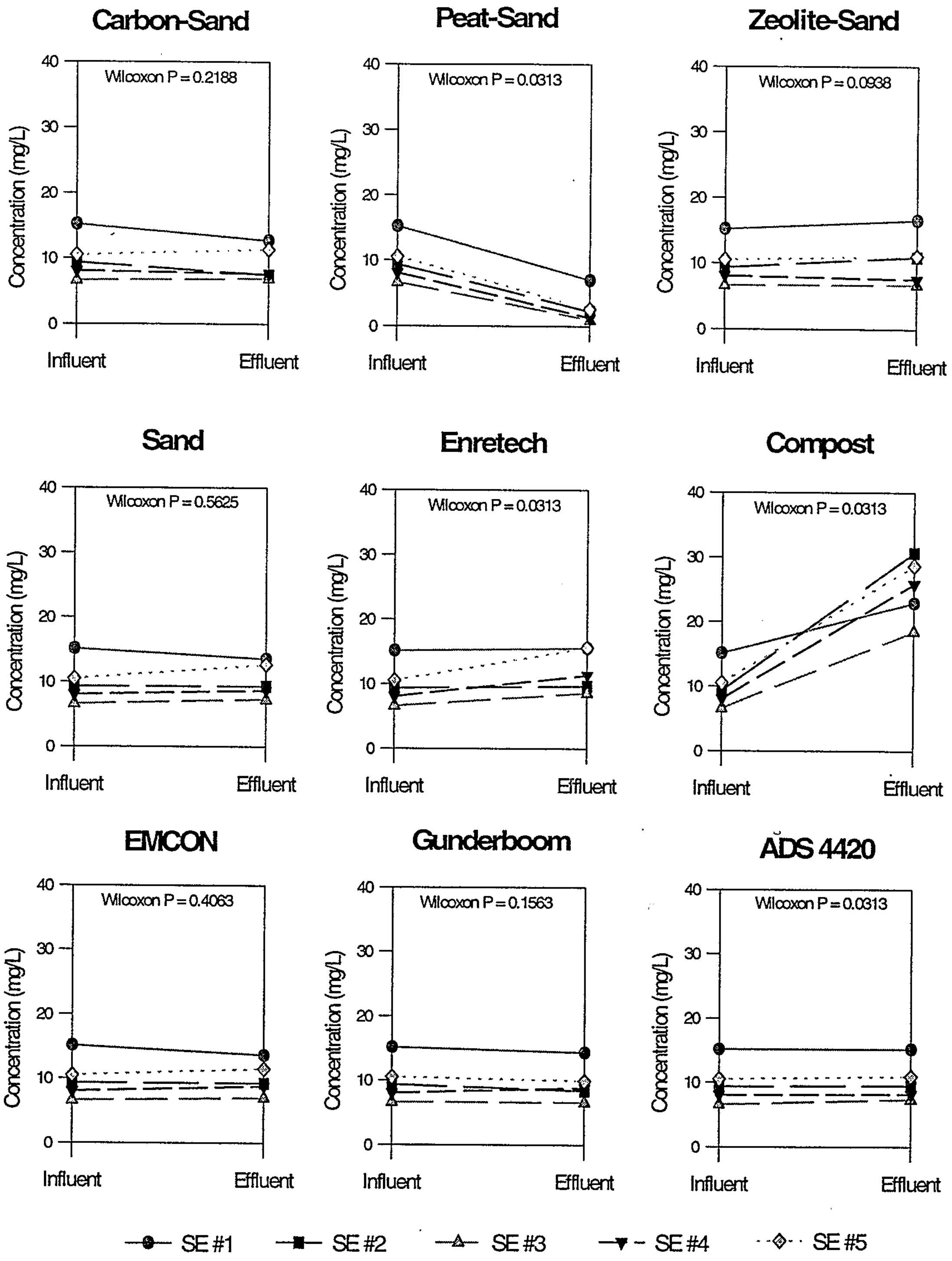
AMMONIUM: Unpretreated Influent



POTASSIUM: Unpretreated Influent



MAGNESIUM: Unpretreated Influent



CALCIUM: Unpretreated Influent

Appendix F:
Solids and Particle Size Distribution

Total Solids
Dissolved Solids
Suspended Solids
Volatile Total Solids
Volatile Dissolved Solids
Volatile Suspended Solids
Particle Size Distribution (1 to 2 µm)
Particle Size Distribution (4 to 5 µm)
Particle Size Distribution (11 to 12 µm)
Particle Size Distribution (1 to 128 µm)

SOLIDS

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Total Solids (mg/L)			Total Dissolved Solids (mg/L)			Total Suspended Solids (mg/L)			Cumulative Volume (um^3/mL)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	72	71	1	64	67	-5	8	4	50	12,832,879	668,128	95
13.1 m	42	48	-14	38	43	-13	4	5	-25	1,415,822	894,578	37
16.4 m	50	55	-10	42	50	-19	8	5	38	1,779,847	632,341	64
20.6 m	53	49	8	46	39	15	7	10	-43	1,952,688	1,521,620	22
25.0 m	85	46	46	52	39	25	33	7	79	1,533,127	1,077,803	30
Peat-Sand												
8.5 m	72	40	44	64	32	50	8	8	0	12,832,879	7,008,453	45
13.1 m	42	46	-10	38	24	37	4	22	-450	1,415,822	6,759,211	-377
16.4 m	50	32	36	42	17	60	8	15	-88	1,779,847	3,856,976	-117
20.6 m	53	39	26	46	23	50	7	16	-129	1,952,688	3,725,962	-91
25.0 m	85	51	40	52	38	27	33	13	61	1,533,127	1,826,743	-19
Zeolite-Sand												
8.5 m	72	77	-7	64	66	-3	8	11	-38	12,832,879	8,223,905	36
13.1 m	42	53	-26	38	40	-5	4	13	-225	1,415,822	10,185,967	-619
16.4 m	50	50	0	42	34	19	8	16	-100	1,779,847	4,176,653	-135
20.6 m	53	53	0	46	50	-9	7	3	57	1,952,688	3,028,150	-55
25.0 m	85	52	39	52	48	8	33	4	88	1,533,127	2,809,189	-83
Compost-Sand												
8.5 m	72	114	-58	64	104	-63	8	10	-25	12,832,879	13,719,042	-7
13.1 m	42	86	-105	38	63	-66	4	23	-475	1,415,822	13,609,301	-861
16.4 m	50	82	-64	42	73	-74	8	9	-13	1,779,847	9,384,445	-427
20.6 m	53	67	-26	46	45	2	7	22	-214	1,952,688	5,915,683	-203
25.0 m	85	73	14	52	63	-21	33	10	70	1,533,127	7,495,351	-389
Enretech-Sand												
8.5 m	72	71	1	64	65	-2	8	6	25	12,832,879	5,976,853	53
13.1 m	42	44	-5	38	10	74	4	34	-750	1,415,822	8,086,190	-471
16.4 m	50	56	-12	42	42	0	8	14	-75	1,779,847	3,752,607	-111
20.6 m	53	52	2	46	35	24	7	17	-143	1,952,688	3,477,412	-78
25.0 m	85	68	20	52	57	-10	33	11	67	1,533,127	3,272,748	-113

SOLIDS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Total Solids (mg/L)			Total Dissolved Solids (mg/L)			Total Suspended Solids (mg/L)			Cumulative Volume (um^3/mL)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	72	81	-13	64	65	-2	8	16	-100	12,832,879	9,362,169	27
13.1 m	42	53	-26	38	26	32	4	27	-575	1,415,822	8,824,918	-523
16.4 m	50	48	4	42	43	-2	8	5	38	1,779,847	3,058,860	-72
20.6 m	53	52	2	46	44	4	7	8	-14	1,952,688	2,882,181	-48
25.0 m	85	68	20	52	56	-8	33	12	64	1,533,127	2,742,452	-79
Sand												
8.5 m	72	66	8	64	63	2	8	3	63	12,832,879	4,225,330	67
13.1 m	42	51	-21	38	35	8	4	16	-300	1,415,822	6,253,006	-342
16.4 m	50	46	8	42	42	0	8	14	-75	1,779,847	2,918,964	-64
20.6 m	53	47	11	46	50	-9	7	13	-86	1,952,688	2,802,032	-43
25.0 m	85	58	32	52	49	6	33	13	61	1,533,127	3,624,544	-136
Gunderboom Fabric												
8.5 m	72	69	4	64	56	13	8	13	-63	12,832,879	10,965,137	15
13.1 m	42	51	-21	38	44	-16	4	7	-75	1,415,822	2,006,783	-42
16.4 m	50	46	8	42	40	5	8	6	25	1,779,847	1,388,839	22
20.6 m	53	47	11	46	36	22	7	11	-57	1,952,688	1,933,883	1
25.0 m	85	58	32	52	46	12	33	12	64	1,533,127	1,552,441	-1
EMCON Fabric												
8.5 m	72	89	-24	64	63	2	8	26	-225	12,832,879	13,119,485	-2
13.1 m	42	34	19	38	22	42	4	12	-200	1,415,822	1,711,857	-21
16.4 m	50	47	6	42	38	10	8	9	-13	1,779,847	1,728,461	3
20.6 m	53	60	-13	46	42	9	7	18	-157	1,952,688	1,505,948	23
25.0 m	85	52	39	52	46	12	33	6	82	1,533,127	2,854,571	-86

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall, 1995

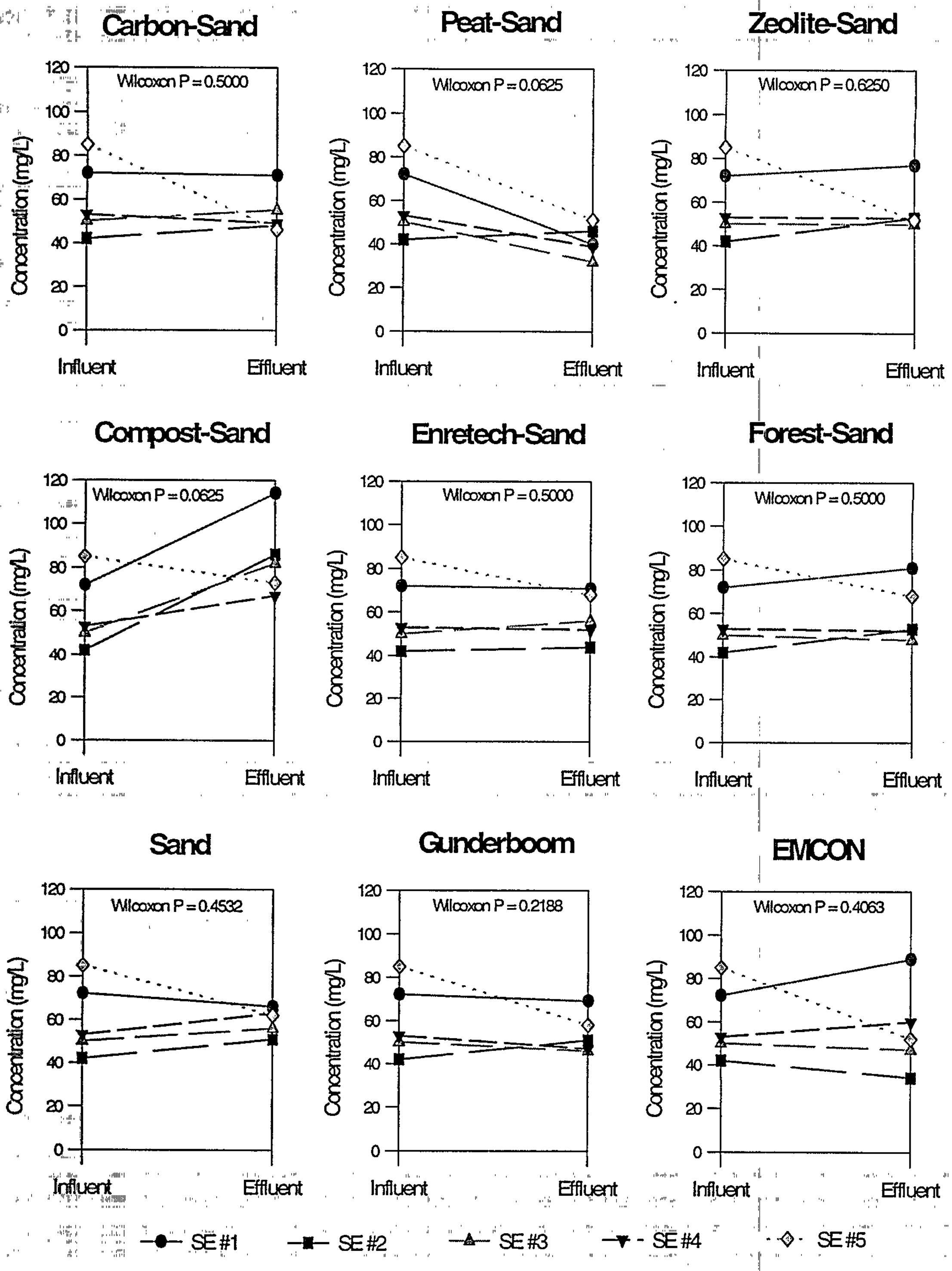
SOLIDS (Continued)

SAMPLE GROUP NAME	Volatile Total Solids (mg/L)			Volatile Dissolved Solids (mg/L)			Volatile Suspended Solids (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
8.5 m	32	18	44	30	10	67	2	8	-300
13.1 m	23	18	22	8	7	13	15	11	27
16.4 m	32	7	78	4	4	0	28	3	89
20.6 m	22	23	-5	18	21	-17	4	2	50
25.0 m	13	17	-31	8	8	0	5	9	-80
Peat-Sand									
8.5 m	32	22	31	30	21	30	2	1	50
13.1 m	23	25	-9	8	12	-50	15	13	13
16.4 m	32	13	59	4	4	0	28	9	68
20.6 m	22	20	9	18	3	83	4	17	-325
25.0 m	13	17	-31	8	15	-88	5	2	60
Zeolite-Sand									
8.5 m	32	20	38	30	19	37	2	1	50
13.1 m	23	23	0	8	7	13	15	16	-7
16.4 m	32	24	25	4	2	50	28	22	21
20.6 m	22	41	-86	18	24	-33	4	17	-325
25.0 m	13	13	0	8	10	-25	5	3	40
Compost-Sand									
8.5 m	32	52	-63	30	47	-57	2	5	-150
13.1 m	23	45	-96	8	33	-313	15	12	20
16.4 m	32	33	-3	4	31	-675	28	2	93
20.6 m	22	26	-18	18	9	50	4	17	-325
25.0 m	13	23	-77	8	19	-138	5	4	20
Enretech-Sand									
8.5 m	32	25	22	30	16	47	2	9	-350
13.1 m	23	18	22	8	5	38	15	13	13
16.4 m	32	13	59	4	12	-200	28	1	96
20.6 m	22	13	41	18	15	17	4	-2	150
25.0 m	13	19	-46	8	17	-113	5	2	60

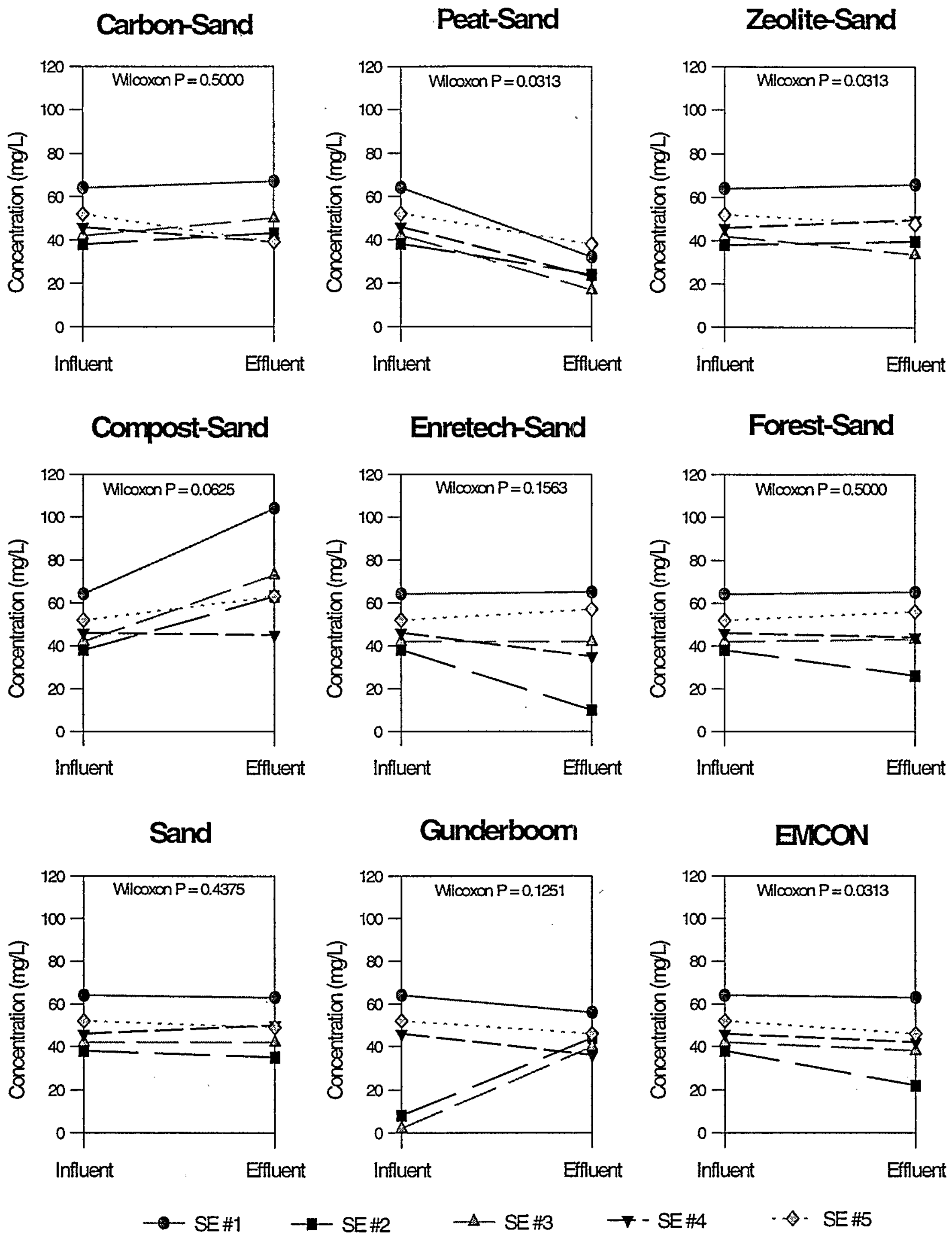
SOLIDS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall, 1995

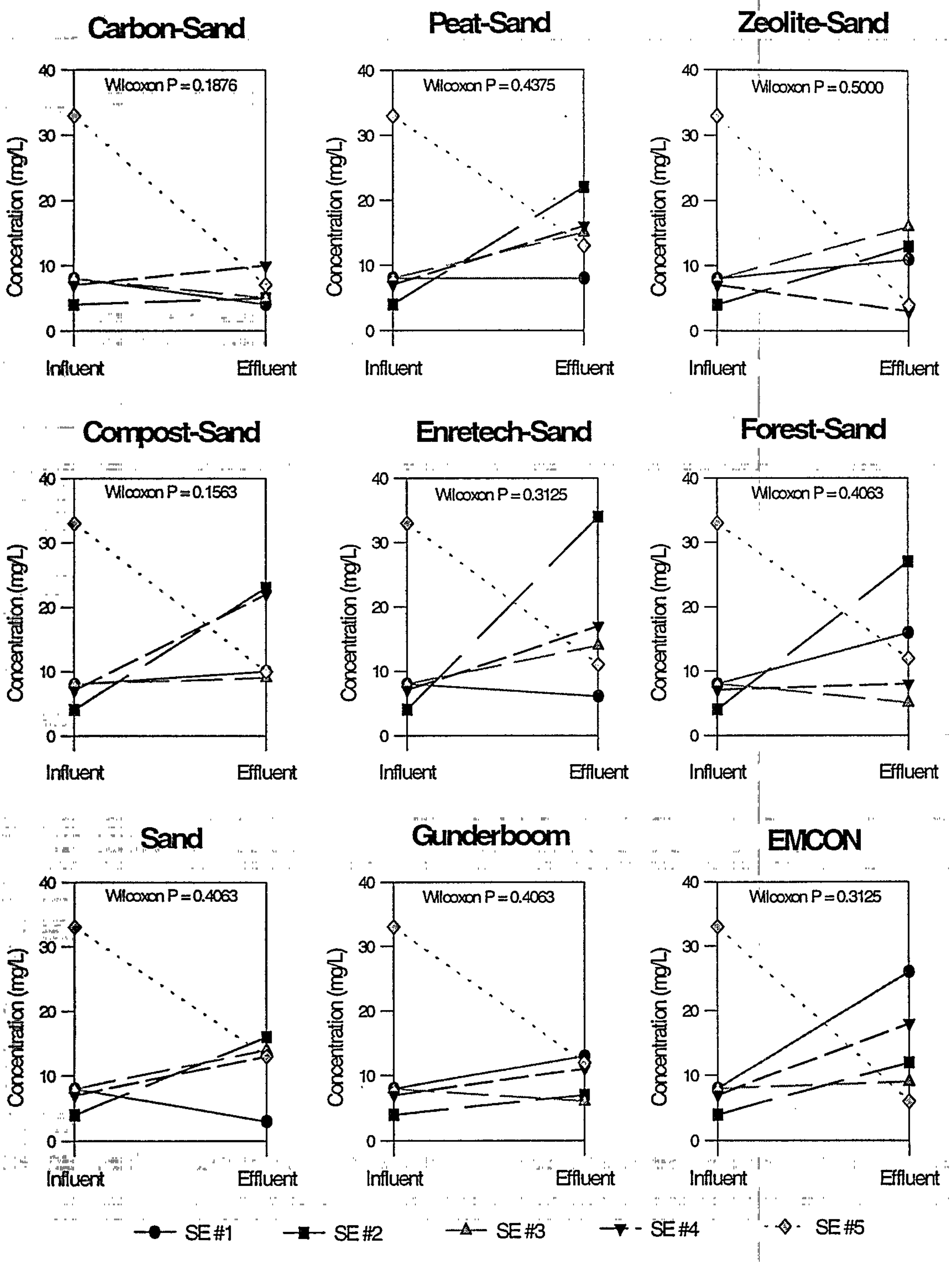
SAMPLE GROUP NAME	Volatile Total Solids (mg/L)			Volatile Dissolved Solids (mg/L)			Volatile Suspended Solids (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand									
8.5 m	32	32	0	30	32	-7	2	0	100
13.1 m	23	18	22	8	14	-75	15	4	73
16.4 m	32	28	13	4	17	-325	28	11	61
20.6 m	22	21	5	18	11	39	4	10	-150
25.0 m	13	14	-8	8	12	-50	5	2	60
Sand									
8.5 m	32	34	-6	30	25	17	2	9	-350
13.1 m	23	9	61	8	7	13	15	2	87
16.4 m	32	28	13	4	9	-125	28	19	32
20.6 m	22	18	18	18	18	0	4	0	100
25.0 m	13	9	31	8	6	25	5	3	40
Gunderboom Fabric									
8.5 m	32	29	9	30	19	37	2	10	-400
13.1 m	23	24	-4	8	28	-250	15	-4	127
16.4 m	32	17	47	4	2	50	28	15	46
20.6 m	22	22	0	18	13	28	4	9	-125
25.0 m	13	17	-31	8	8	0	5	9	-80
EMCON Fabric									
8.5 m	32	41	-28	30	12	60	2	29	-1,350
13.1 m	23	16	30	8	3	63	15	13	13
16.4 m	32	22	31	4	16	-300	28	6	79
20.6 m	22	17	23	18	6	67	4	11	-175
25.0 m	13	13	0	8	8	0	5	5	0



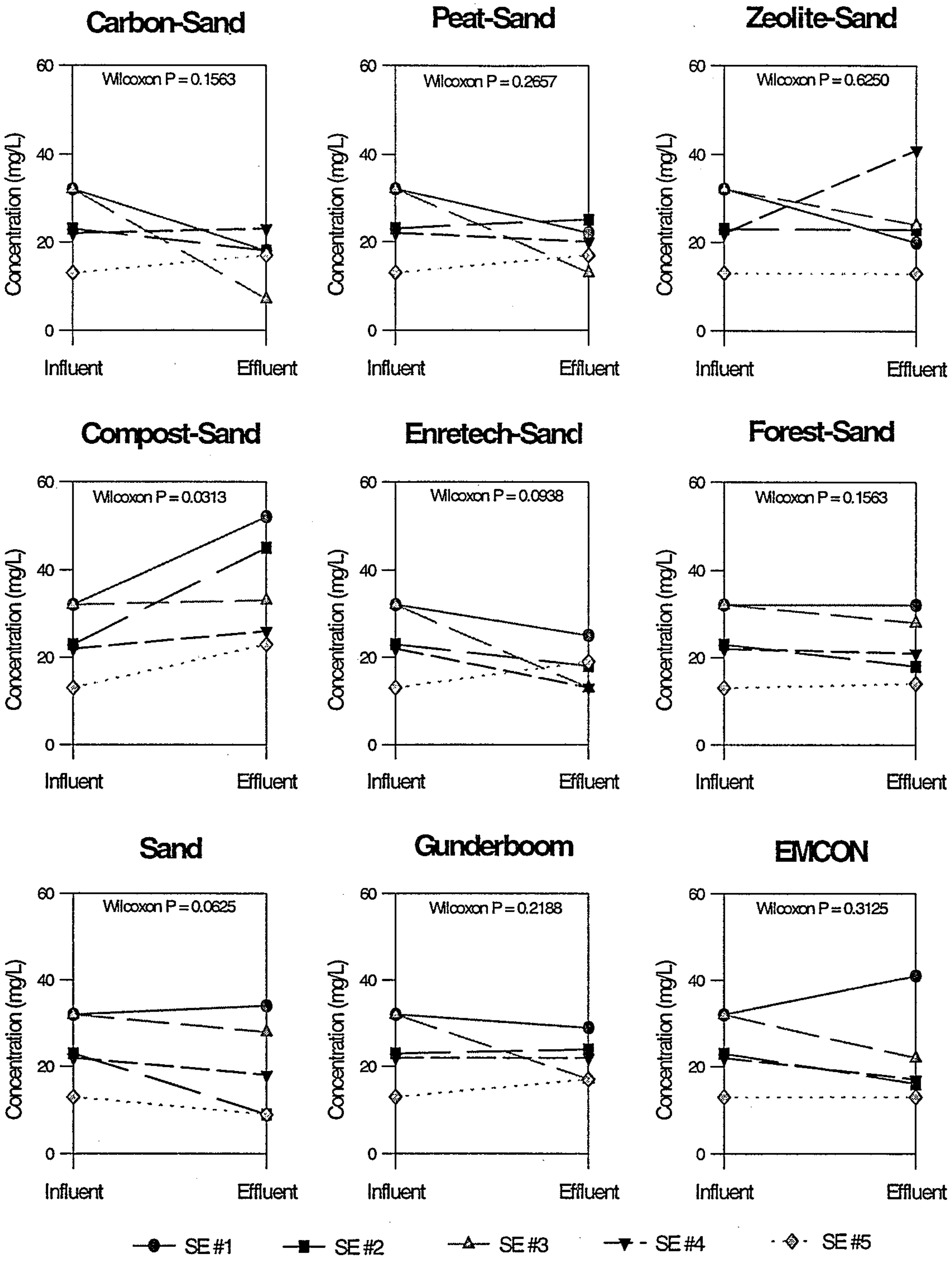
TOTAL SOLIDS: Pre-Settled Influent



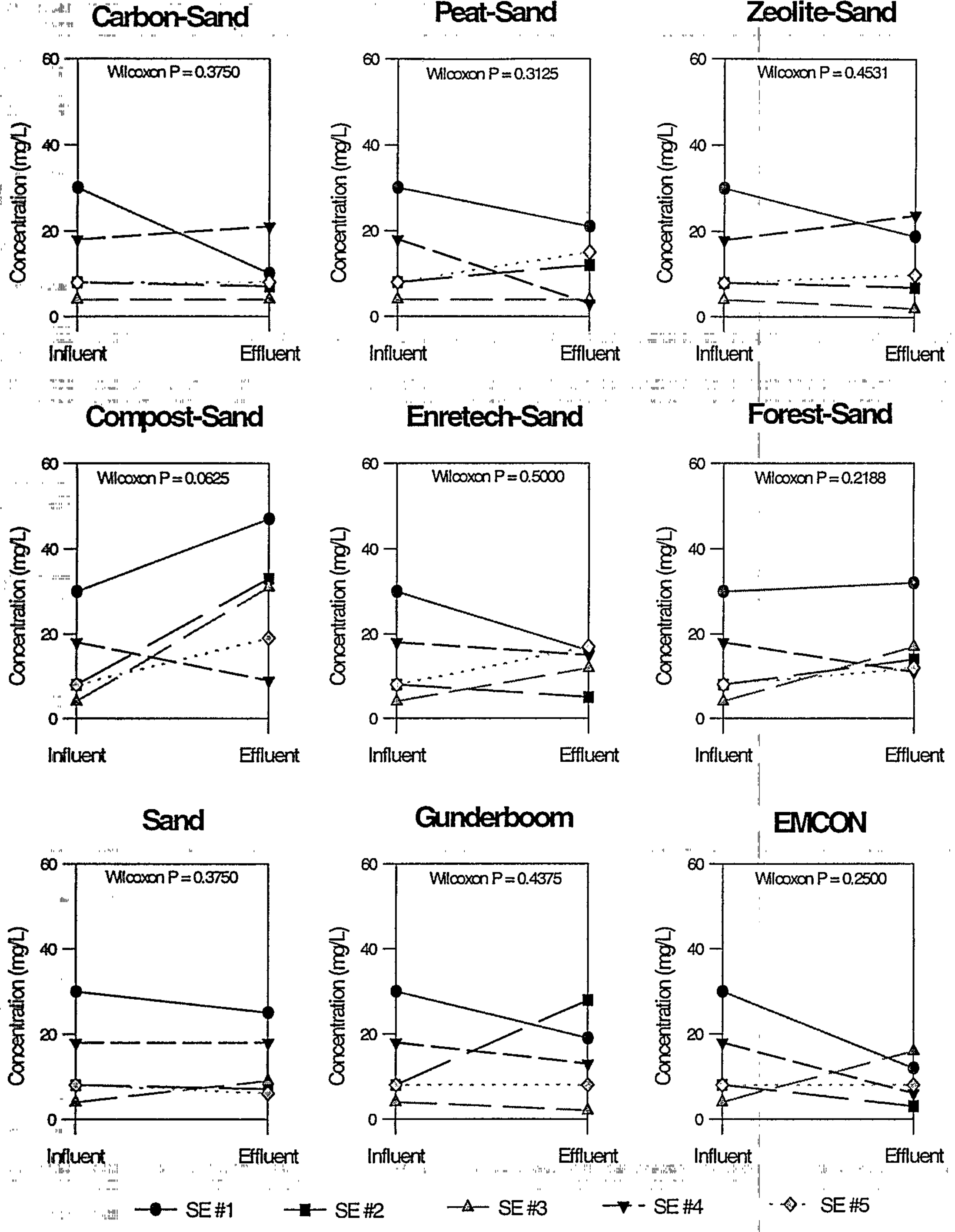
DISSOLVED SOLIDS: PreSettled Influent



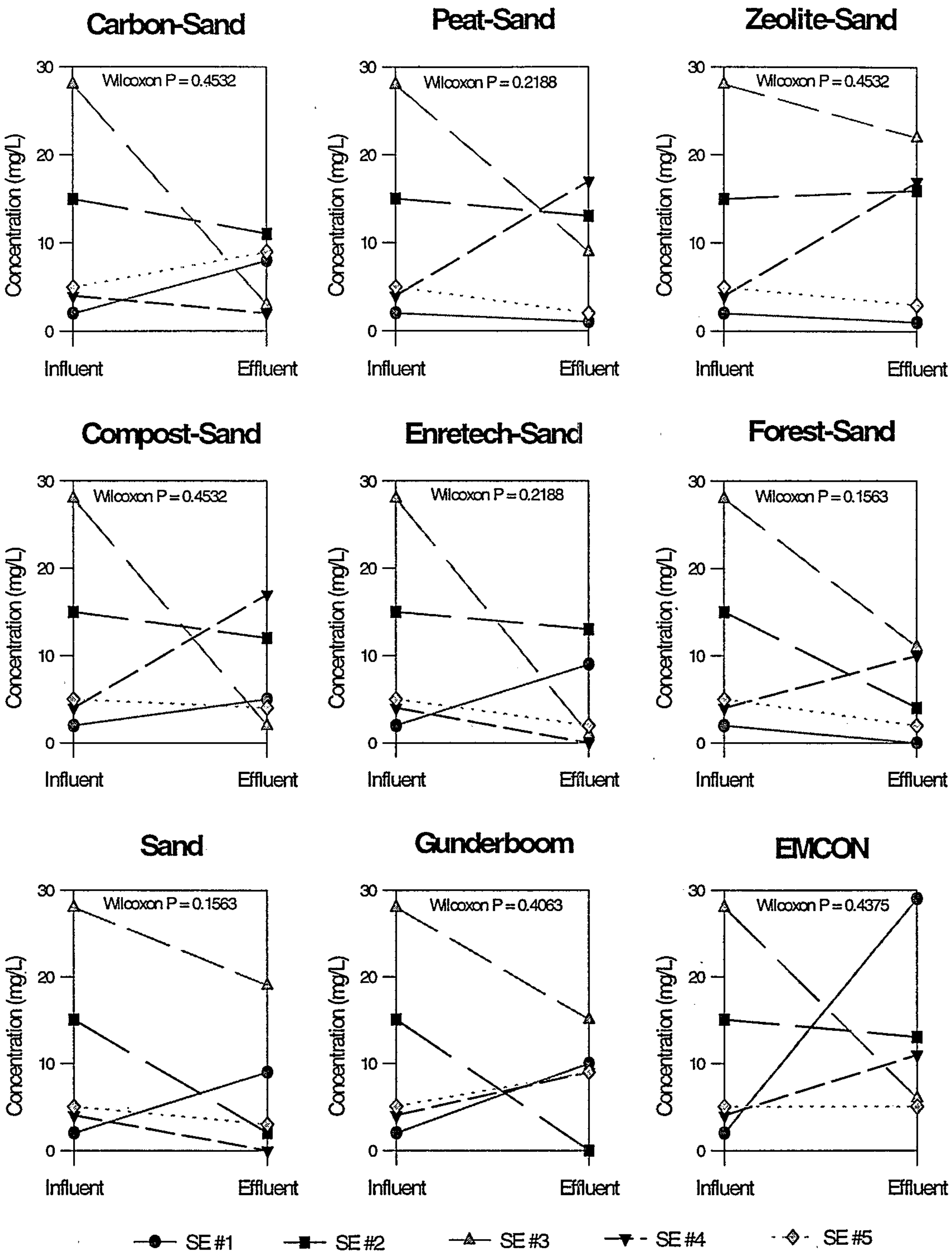
SUSPENDED SOLIDS: PreSettled Influent



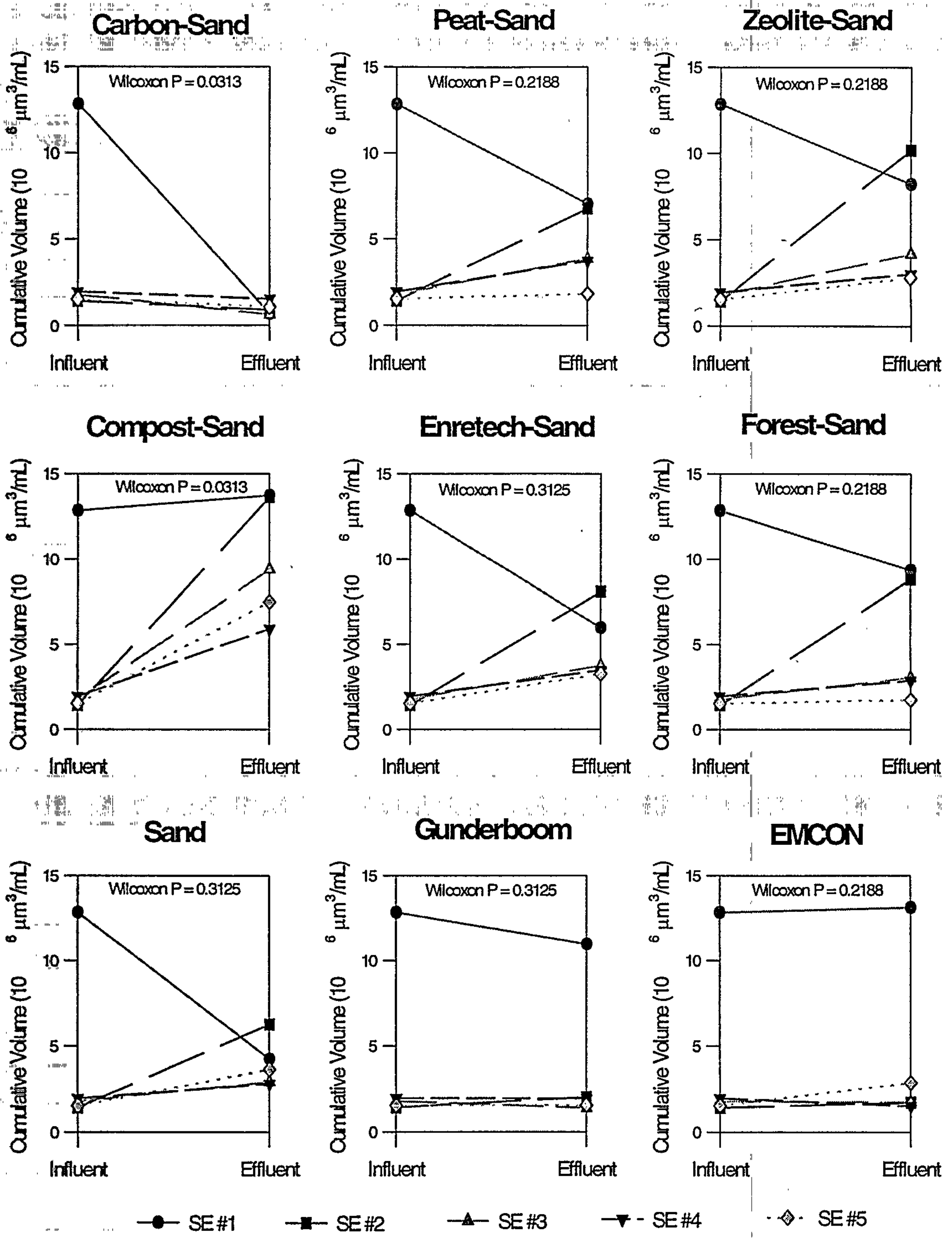
VOLATILE TOTAL SOLIDS: PreSettled Influent



VOLATILE DISSOLVED SOLIDS: PreSettled Influent



VOLATILE SUSPENDED SOLIDS: PreSettled Influent



PARTICLE SIZE DISTRIBUTION: PreSettled Influent (1 to 128 µm)

SOLIDS

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Total Solids (mg/L)			Total Dissolved Solids (mg/L)			Total Suspended Solids (mg/L)			Cumulative Volume ($\mu m^3/mL$)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
1.1 m	168	342	-104	137	324	-136	31	18	42	24,816,576	2,492,405	90
2.2 m	161	173	-7	145	162	-12	16	11	31	15,145,581	4,445,555	71
3.3 m	53	71	-34	43	60	-40	10	11	-10	4,581,296	1,988,827	57
4.4 m	67	70	-4	54	73	-35	13	0	100	13,119,185	1,594,842	88
5.5 m	100	81	19	76	80	-5	24	1	96	30,742,002	1,013,899	97
Peat-Sand												
1.1 m	168	226	-35	137	184	-34	31	42	-35	24,816,576	15,800,901	36
2.2 m	161	163	-1	145	154	-6	16	9	44	15,145,581	4,169,260	72
3.3 m	53	83	-57	43	68	-58	10	15	-50	4,581,296	7,348,391	-60
4.4 m	67	76	-13	54	60	-11	13	16	-23	13,119,185	11,733,902	11
5.5 m	100	74	26	76	62	18	24	12	50	30,742,002	5,766,312	81
Zeolite-Sand												
1.1 m	168	177	-5	137	139	-1	31	38	-23	24,816,576	10,957,558	56
2.2 m	161	152	6	145	143	1	16	9	44	15,145,581	4,205,814	72
3.3 m	53	58	-9	43	56	-30	10	2	80	4,581,296	3,463,733	24
4.4 m	67	71	-6	54	61	-13	13	10	23	13,119,185	6,768,128	48
5.5 m	100	85	15	76	92	-21	24	0	100	30,742,002	2,738,344	91
Sand												
1.1 m	168	135	20	137	124	9	31	11	65	24,816,576	4,497,096	82
2.2 m	161	149	7	145	138	5	16	11	31	15,145,581	2,731,588	82
3.3 m	53	53	0	43	52	-21	10	1	90	4,581,296	5,293,040	-16
4.4 m	67	59	12	54	57	-6	13	2	85	13,119,185	2,540,314	81
5.5 m	100	85	15	76	105	-38	24	0	100	30,742,002	1,398,224	95
Enretech												
1.1 m	168	223	-33	137	216	-58	31	7	77	24,816,576	6,262,257	75
2.2 m	161	272	-69	145	251	-73	16	21	-31	15,145,581	7,978,896	47
3.3 m	53	104	-96	43	90	-109	10	14	-40	4,581,296	12,031,468	-163
4.4 m	67	127	-90	54	89	-65	13	38	-192	13,119,185	19,378,620	-48
5.5 m	100	97	3	76	97	-28	24	0	100	30,742,002	3,560,360	88

SOLIDS (Continued)

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Total Solids (mg/L)			Total Dissolved Solids (mg/L)			Total Suspended Solids (mg/L)			Cumulative Volume (μm^3/mL)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost												
1.1 m	168	303	-80	137	276	-101	31	27	13	24,816,576	3,943,957	84
2.2 m	161	347	-116	145	334	-130	16	13	19	15,145,581	7,107,894	53
3.3 m	53	213	-302	43	190	-342	10	0	100	4,581,296	8,829,422	-93
4.4 m	67	247	-269	54	222	-311	13	25	-92	13,119,185	11,262,428	14
5.5 m	100	220	-120	76	215	-183	24	5	79	30,742,002	6,304,884	79
EMCON Fabric												
1.1 m	168	152	10	137	141	-3	31	11	65	24,816,576	12,861,128	48
2.2 m	161	149	7	145	143	1	16	6	63	15,145,581	6,126,888	60
3.3 m	53	52	2	43	53	-23	10	0	100	4,581,296	4,406,809	4
4.4 m	67	67	0	54	52	4	13	15	-15	13,119,185	10,055,400	23
5.5 m	100	81	19	76	74	3	24	7	71	30,742,002	13,838,937	55
Gunderboom Fabric												
1.1 m	168	135	20	137	134	2	31	1	97	24,816,576	11,809,218	52
2.2 m	161	144	11	145	123	15	16	21	-31	15,145,581	8,230,659	46
3.3 m	53	57	-8	43	49	-14	10	8	20	4,581,296	3,973,314	13
4.4 m	67	65	3	54	57	-6	13	8	38	13,119,185	10,177,487	22
5.5 m	100	77	23	76	60	21	24	17	29	30,742,002	7,408,825	76
ADS 4420 Fabric												
1.1 m	168	149	11	137	139	-1	31	10	68	24,816,576	10,957,561	56
2.2 m	161	148	8	145	129	11	16	19	-19	15,145,581	13,689,703	10
3.3 m	53	53	0	43	49	-14	10	4	60	4,581,296	4,523,369	1
4.4 m	67	70	-4	54	58	-7	13	12	8	13,119,185	17,360,162	-32
5.5 m	100	91	9	76	67	12	24	24	0	30,742,002	24,720,218	20

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

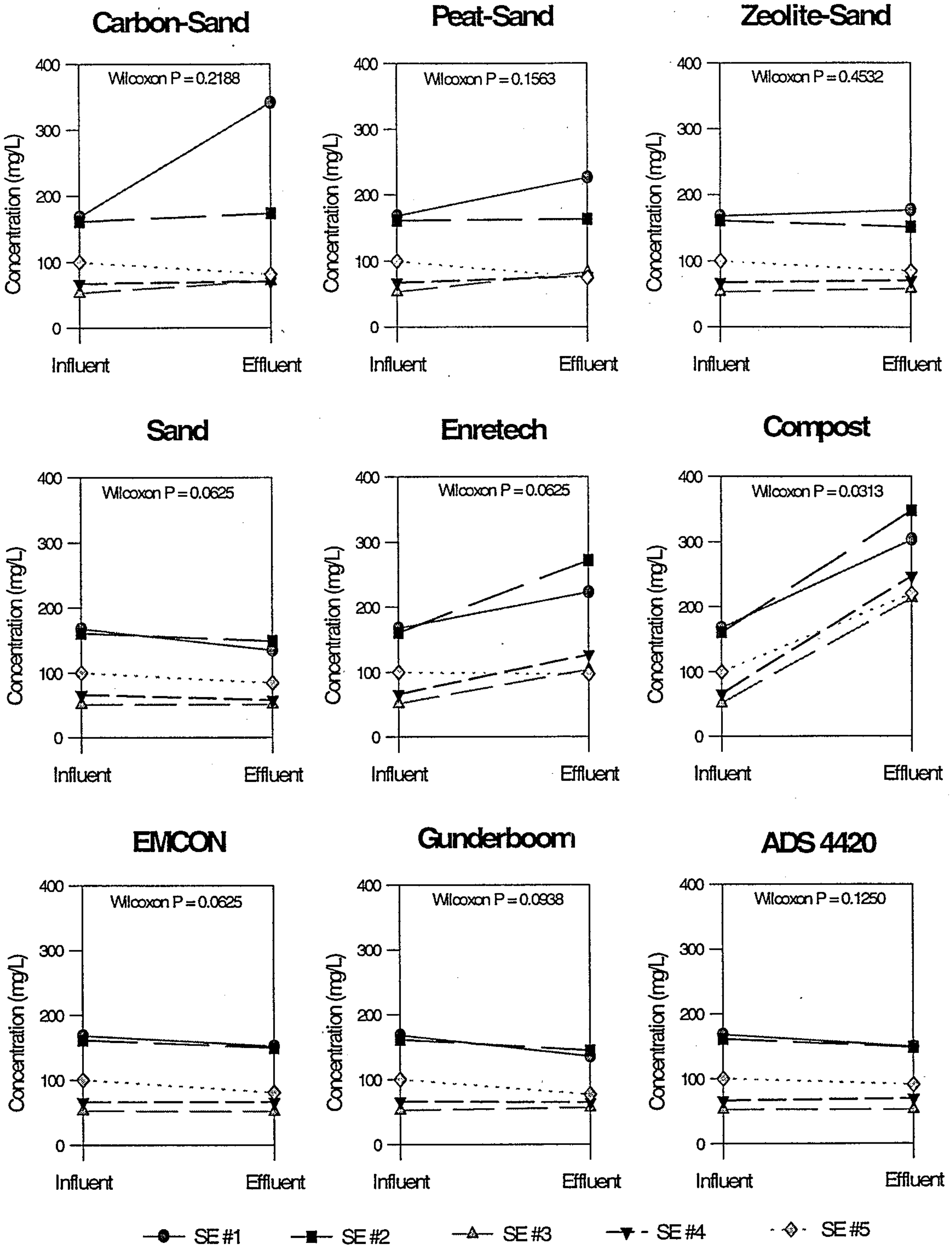
SOLIDS (Continued)

SAMPLE GROUP NAME	Volatile Total Solids (mg/L)			Volatile Dissolved Solids (mg/L)			Volatile Suspended Solids (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
1.1 m	59	23	61	44	12	73	15	11	27
2.2 m	50	14	72	47	14	70	3	0	100
3.3 m	20	5	75	10	5	50	10	0	100
4.4 m	29	6	79	27	12	56	2	0	100
5.5 m	37	12	68	30	16	47	7	0	100
Peat-Sand									
1.1 m	59	82	-39	44	65	-48	15	17	-13
2.2 m	50	71	-42	47	60	-28	3	11	-267
3.3 m	20	44	-120	10	20	-100	10	24	-140
4.4 m	29	32	-10	27	37	-37	2	0	100
5.5 m	37	31	16	30	27	10	7	4	43
Zeolite-Sand									
1.1 m	59	56	5	44	48	-9	15	8	47
2.2 m	50	44	12	47	37	21	3	7	-133
3.3 m	20	19	5	10	14	-40	10	5	50
4.4 m	29	22	24	27	30	-11	2	0	100
5.5 m	37	23	38	30	37	-23	7	0	100
Sand									
1.1 m	59	52	12	44	40	9	15	12	20
2.2 m	50	44	12	47	38	19	3	6	-100
3.3 m	20	16	20	10	18	-80	10	0	100
4.4 m	29	21	28	27	23	15	2	0	100
5.5 m	37	27	27	30	30	0	7	0	100
Enretech									
1.1 m	59	101	-71	44	83	-89	15	18	-20
2.2 m	50	122	-144	47	121	-157	3	1	67
3.3 m	20	39	-95	10	32	-220	10	7	30
4.4 m	29	64	-121	27	46	-70	2	18	-800
5.5 m	37	30	19	30	31	-3	7	0	100

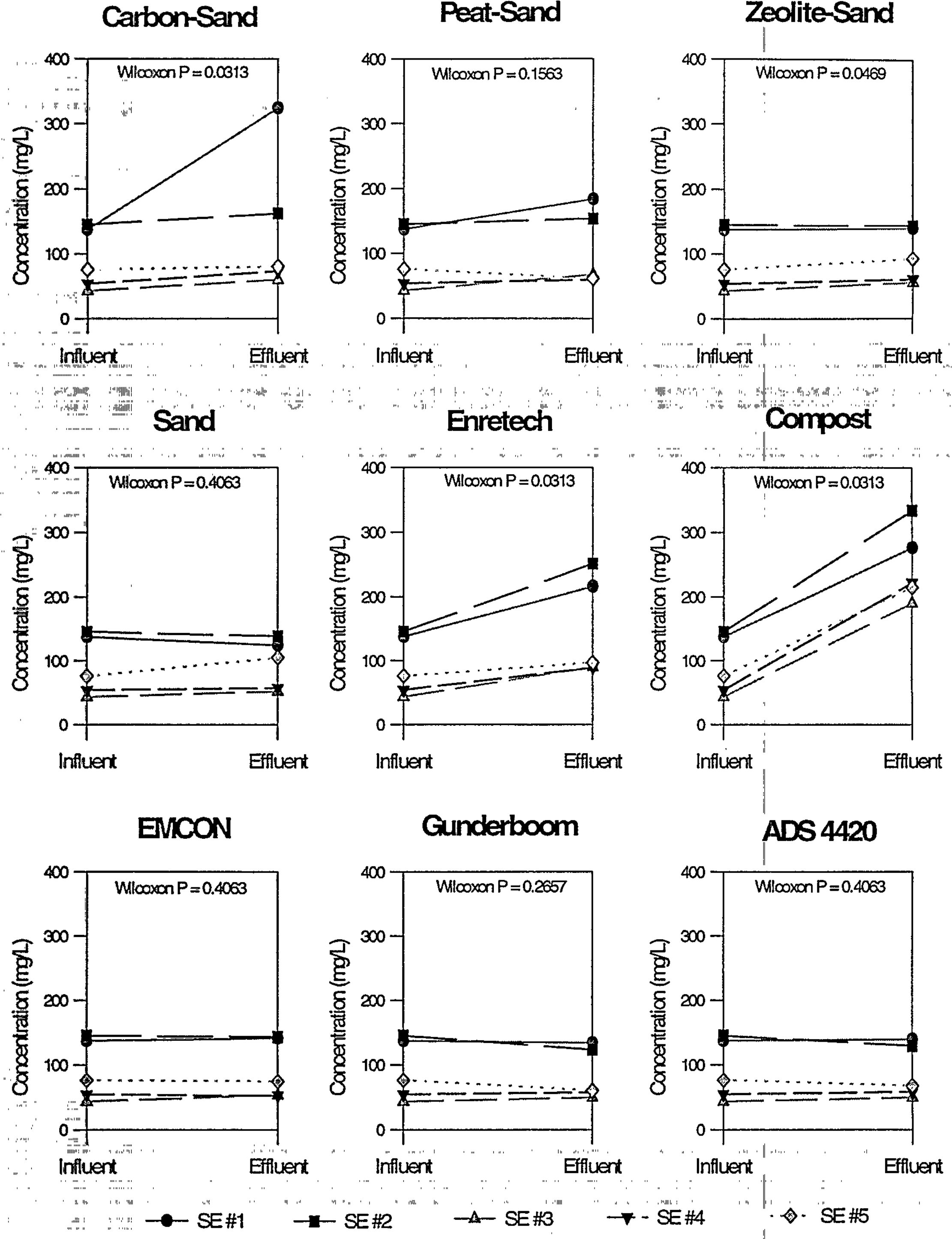
FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SOLIDS (Continued)

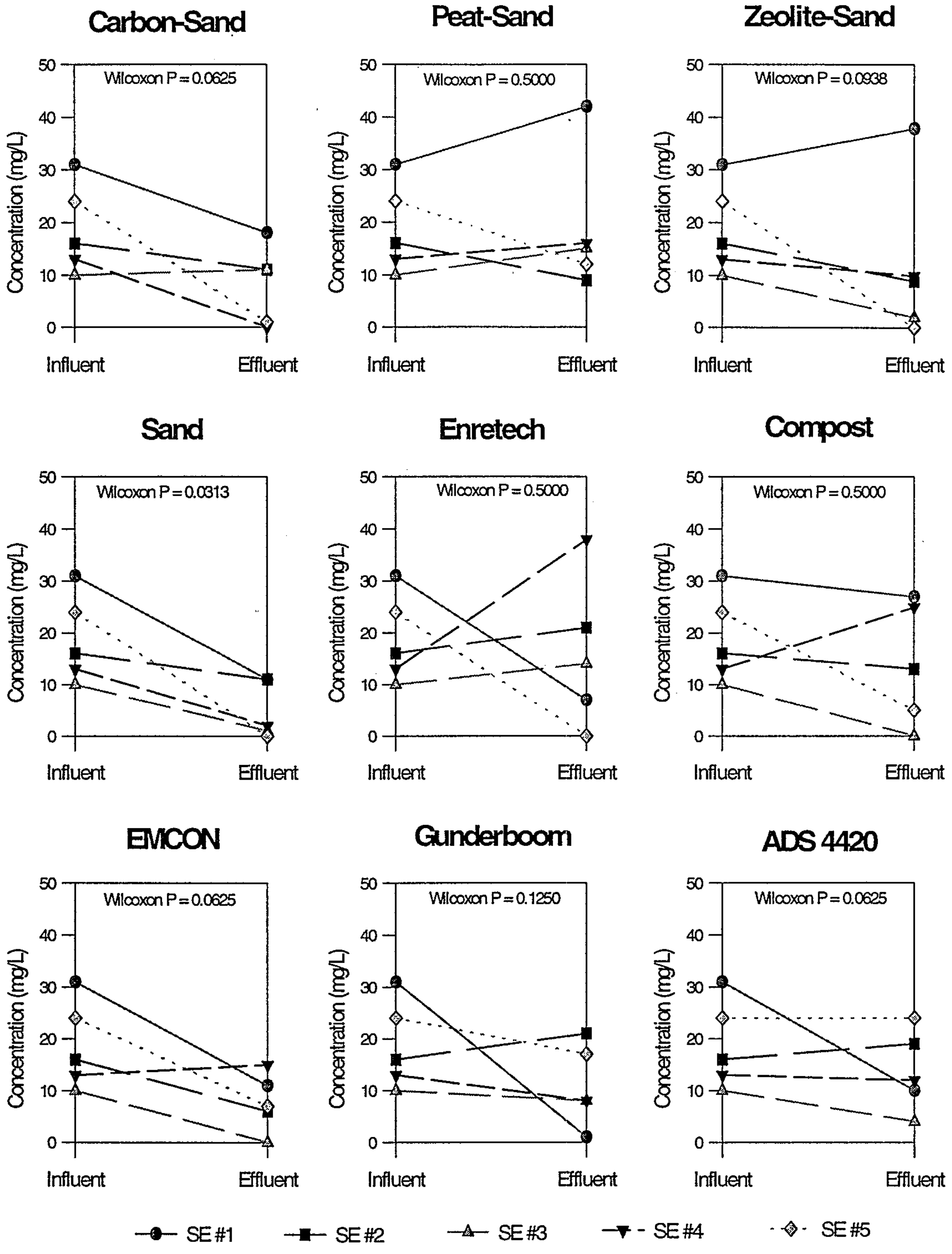
SAMPLE GROUP NAME	Volatile Total Solids (mg/L)			Volatile Dissolved Solids (mg/L)			Volatile Suspended Solids (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost									
1.1 m	59	149	-153	44	127	-189	15	22	-47
2.2 m	50	152	-204	47	107	-128	3	45	-1,400
3.3 m	20	95	-375	10	67	-570	10	28	-180
4.4 m	29	110	-279	27	105	-289	2	5	-150
5.5 m	37	94	-154	30	100	-233	7	0	100
EMCON Fabric									
1.1 m	59	65	-10	44	52	-18	15	13	13
2.2 m	50	42	16	47	42	11	3	0	100
3.3 m	20	17	15	10	16	-60	10	1	90
4.4 m	29	21	28	27	18	33	2	3	-50
5.5 m	37	32	14	30	24	20	7	8	-14
Gunderboom Fabric									
1.1 m	59	49	17	44	49	-11	15	0	100
2.2 m	50	37	26	47	32	32	3	5	-67
3.3 m	20	26	-30	10	14	-40	10	12	-20
4.4 m	29	20	31	27	25	7	2	0	100
5.5 m	37	24	35	30	15	50	7	9	-29
ADS 4420 Fabric									
1.1 m	59	56	5	44	52	-18	15	4	73
2.2 m	50	44	12	47	34	28	3	10	-233
3.3 m	20	19	5	10	16	-60	10	3	70
4.4 m	29	26	10	27	18	33	2	8	-300
5.5 m	37	30	19	30	21	30	7	9	-29



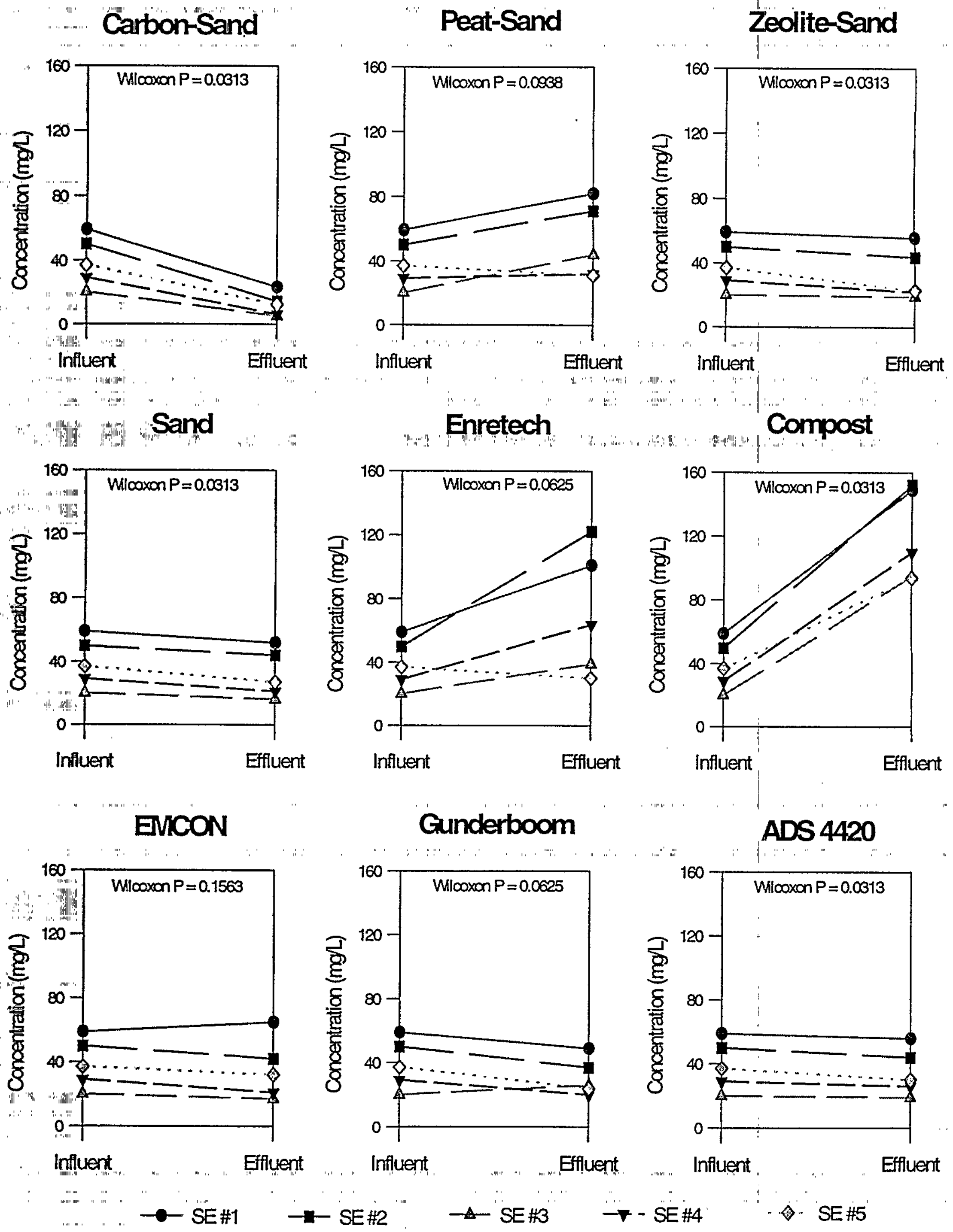
TOTAL SOLIDS: Unpretreated Influent



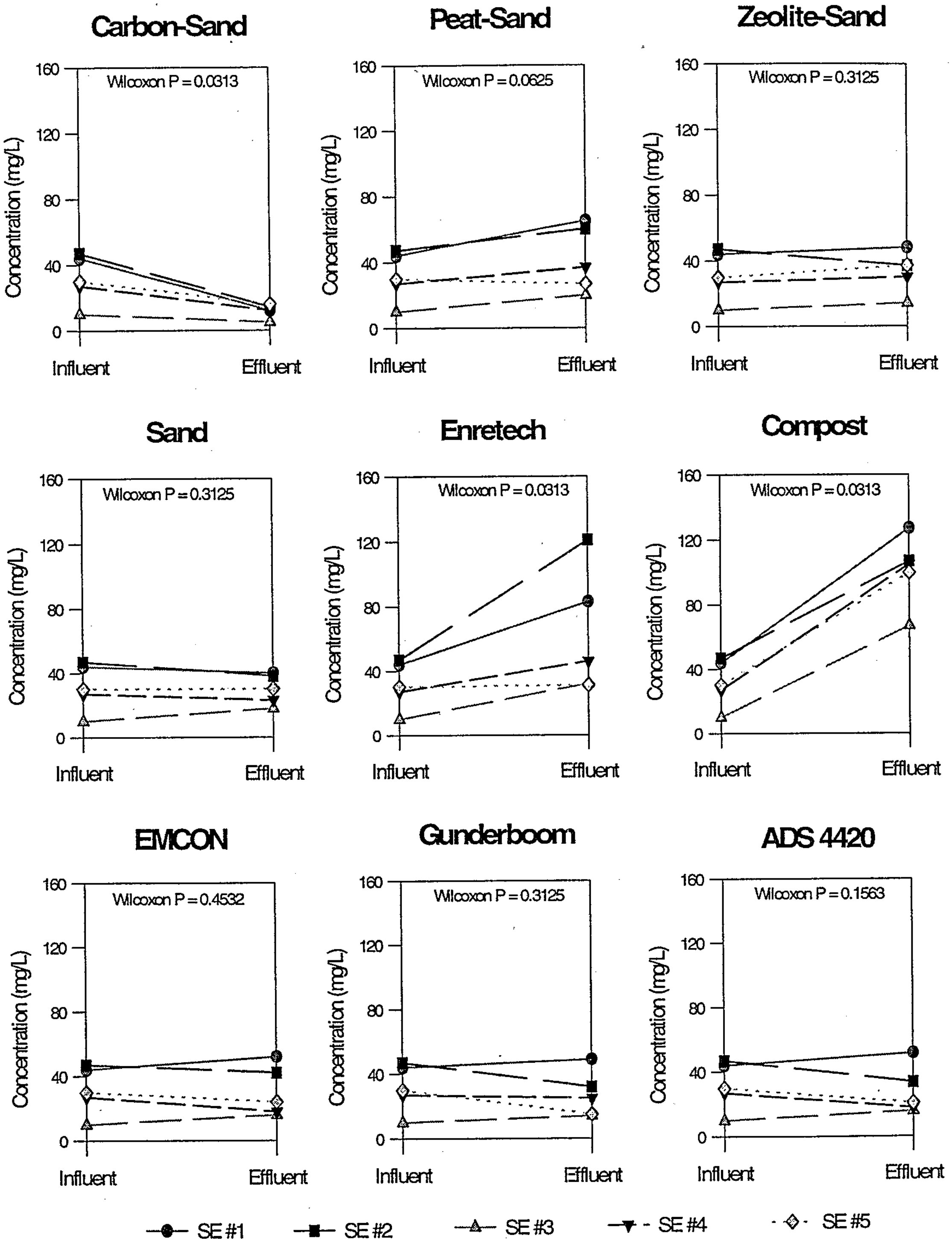
DISSOLVED SOLIDS: Unpretreated Influent



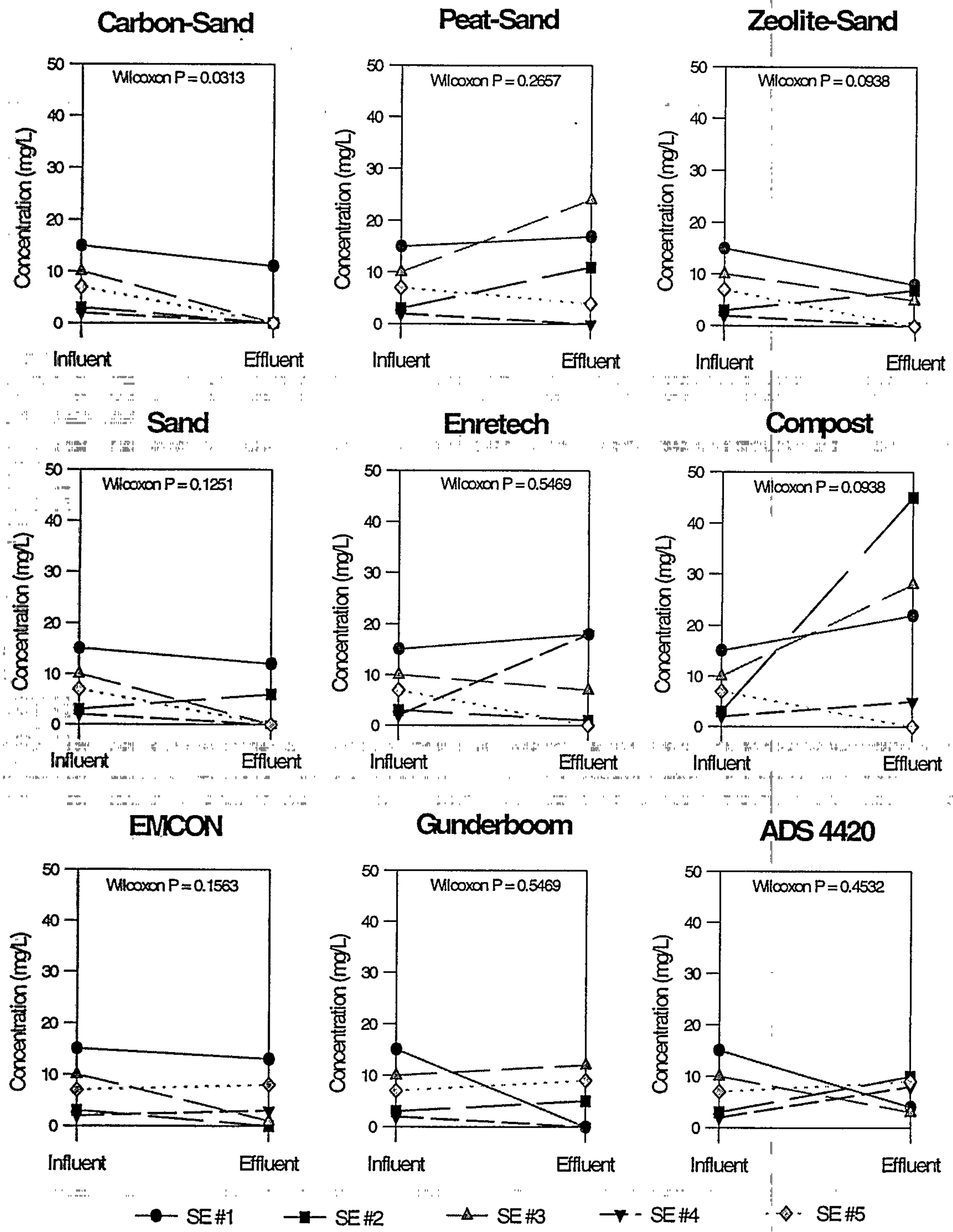
SUSPENDED SOLIDS: Unpretreated Influent



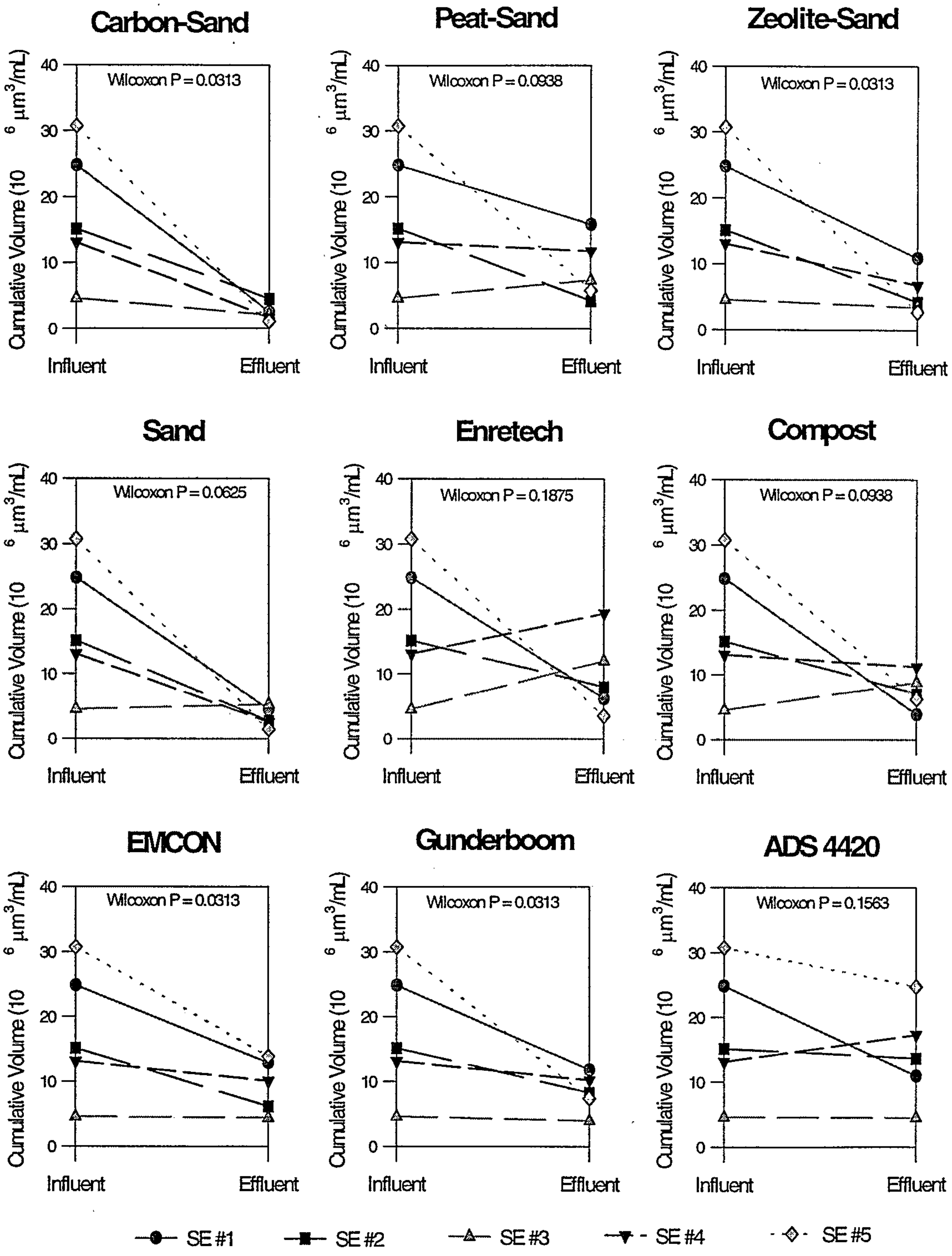
VOLATILE TOTAL SOLIDS: Unpretreated Influent



VOLATILE DISSOLVED SOLIDS: Unpretreated Influent



VOLATILE SUSPENDED SOLIDS: Unpretreated Influent



PARTICLE SIZE DISTRIBUTION: Unpretreated Influent (1 to 128 µm)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

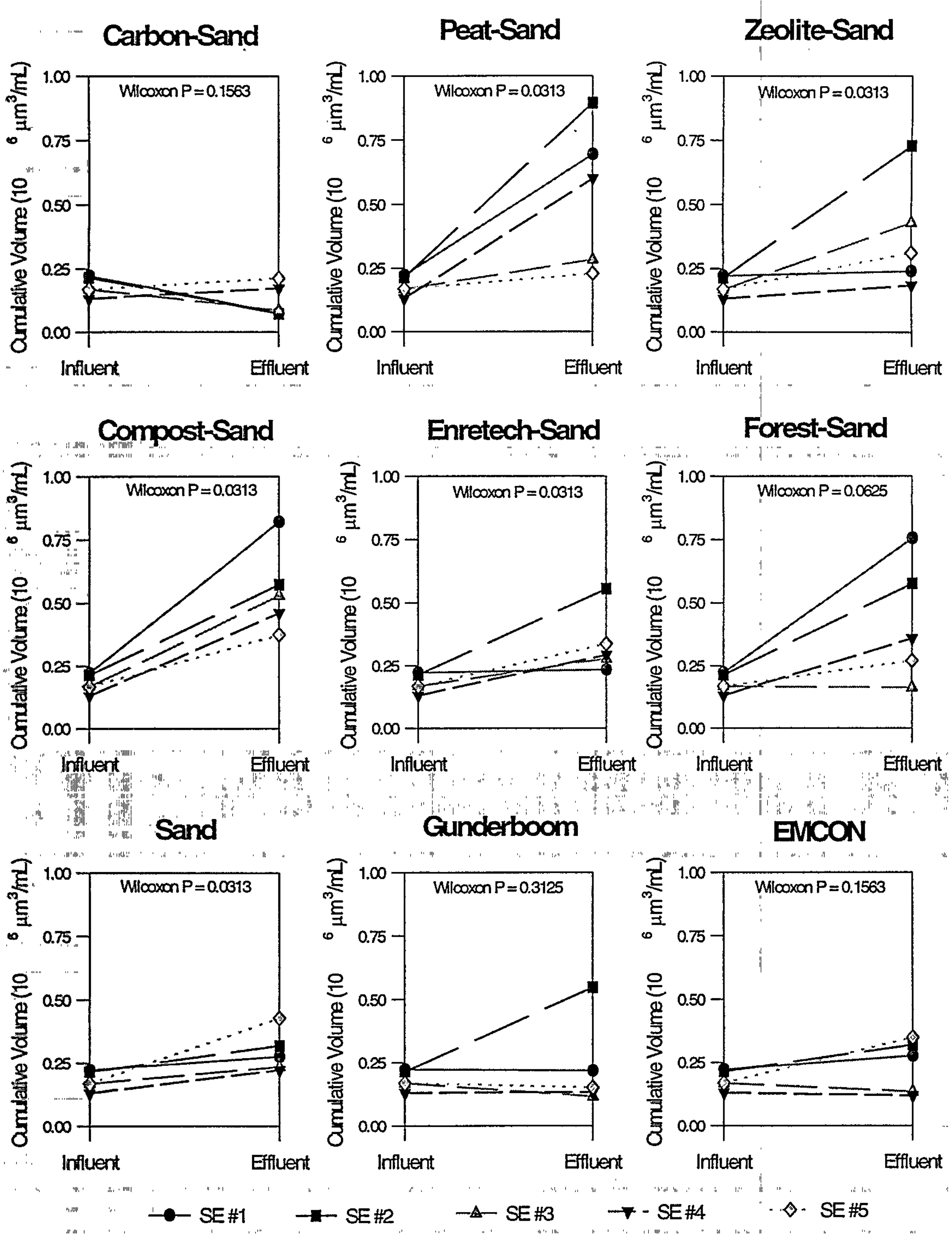
PSD

SAMPLE GROUP NAME	1 - 2 μm (μm^3/mL)			4 - 5 μm (μm^3/mL)			11 - 12.5 μm (μm^3/mL)			Cumulative (μm^3/mL)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	222,239	73,194	67	4,736,682	46,174	99	347,726	26,533	92	12,832,879	668,128	95
13.1 m	213,269	69,880	67	163,202	218,049	-34	92,550	31,390	66	1,415,822	894,578	37
16.4 m	166,700	84,416	49	407,270	118,526	71	86,165	25,044	71	1,779,847	632,341	64
20.6 m	129,761	170,640	-32	200,303	318,251	-59	149,220	53,154	64	1,952,688	1,521,620	22
25.0 m	167,036	211,046	-26	274,109	215,032	22	68,495	19,443	72	1,533,127	1,077,803	30
Peat-Sand												
8.5 m	222,239	693,875	-212	4,736,682	676,772	86	347,726	471,232	-36	12,832,879	7,008,453	45
13.1 m	213,269	894,504	-319	163,202	1,214,485	-644	92,550	317,581	-243	1,415,822	6,759,211	-377
16.4 m	166,700	283,408	-70	407,270	443,501	-9	86,165	348,451	-304	1,779,847	3,856,976	-117
20.6 m	129,761	600,781	-363	200,303	537,081	-168	149,220	194,459	-30	1,952,688	3,725,962	-91
25.0 m	167,036	228,632	-37	274,109	247,232	10	68,495	138,451	-102	1,533,127	1,826,743	-19
Zeolite-Sand												
8.5 m	222,239	241,764	-9	4,736,682	2,922,408	38	347,726	216,200	38	12,832,879	8,223,905	36
13.1 m	213,269	728,894	-242	163,202	2,528,087	-1,449	92,550	420,424	-354	1,415,822	10,185,967	-619
16.4 m	166,700	431,105	-159	407,270	909,122	-123	86,165	37,400	57	1,779,847	4,176,653	-135
20.6 m	129,761	185,623	-43	200,303	575,264	-187	149,220	227,406	-52	1,952,688	3,028,150	-55
25.0 m	167,036	314,194	-88	274,109	548,044	-100	68,495	139,254	-103	1,533,127	2,809,189	-83
Compost-Sand												
8.5 m	222,239	820,501	-269	4,736,682	3,817,580	19	347,726	653,236	-88	12,832,879	13,719,042	-7
13.1 m	213,269	572,717	-169	163,202	3,176,067	-1,846	92,550	418,510	-352	1,415,822	13,609,301	-861
16.4 m	166,700	529,223	-217	407,270	2,755,175	-576	86,165	179,713	-109	1,779,847	9,384,445	-427
20.6 m	129,761	460,179	-255	200,303	1,474,107	-636	149,220	94,060	37	1,952,688	5,915,653	-203
25.0 m	167,036	374,743	-124	274,109	1,164,508	-325	68,495	437,658	-539	1,533,127	7,495,351	-389
Enretech-Sand												
8.5 m	222,239	234,755	-6	4,736,682	1,652,382	65	347,726	182,939	47	12,832,879	5,976,853	53
13.1 m	213,269	555,774	-161	163,202	1,852,568	-1,035	92,550	383,970	-315	1,415,822	8,086,190	-471
16.4 m	166,700	279,178	-67	407,270	959,072	-135	86,165	176,915	-105	1,779,847	3,752,607	-111
20.6 m	129,761	293,878	-126	200,303	584,853	-192	149,220	78,111	48	1,952,688	3,477,412	-78
25.0 m	167,036	337,927	-102	274,109	688,576	-151	68,495	58,541	15	1,533,127	3,272,748	-113

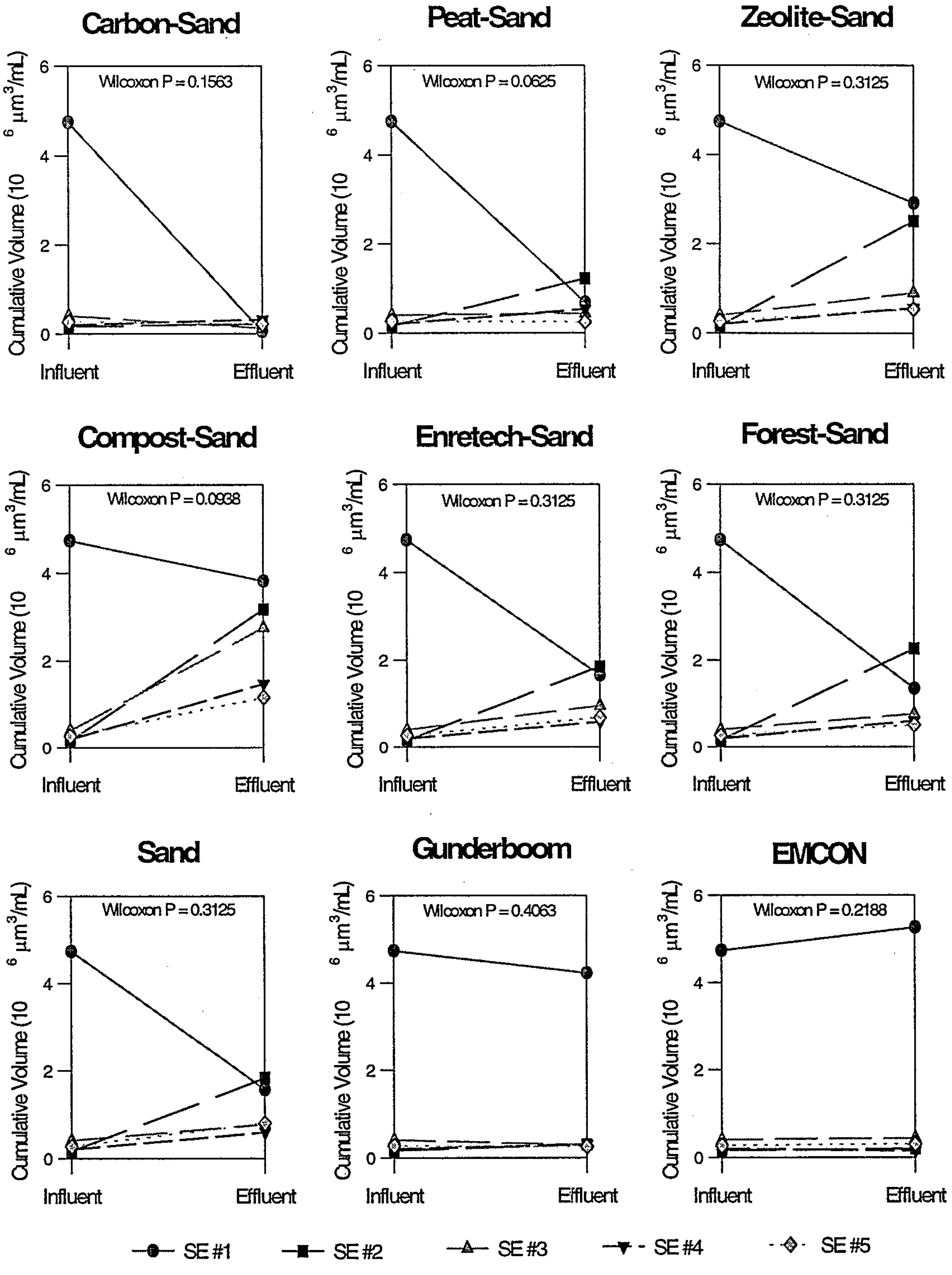
PSD (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

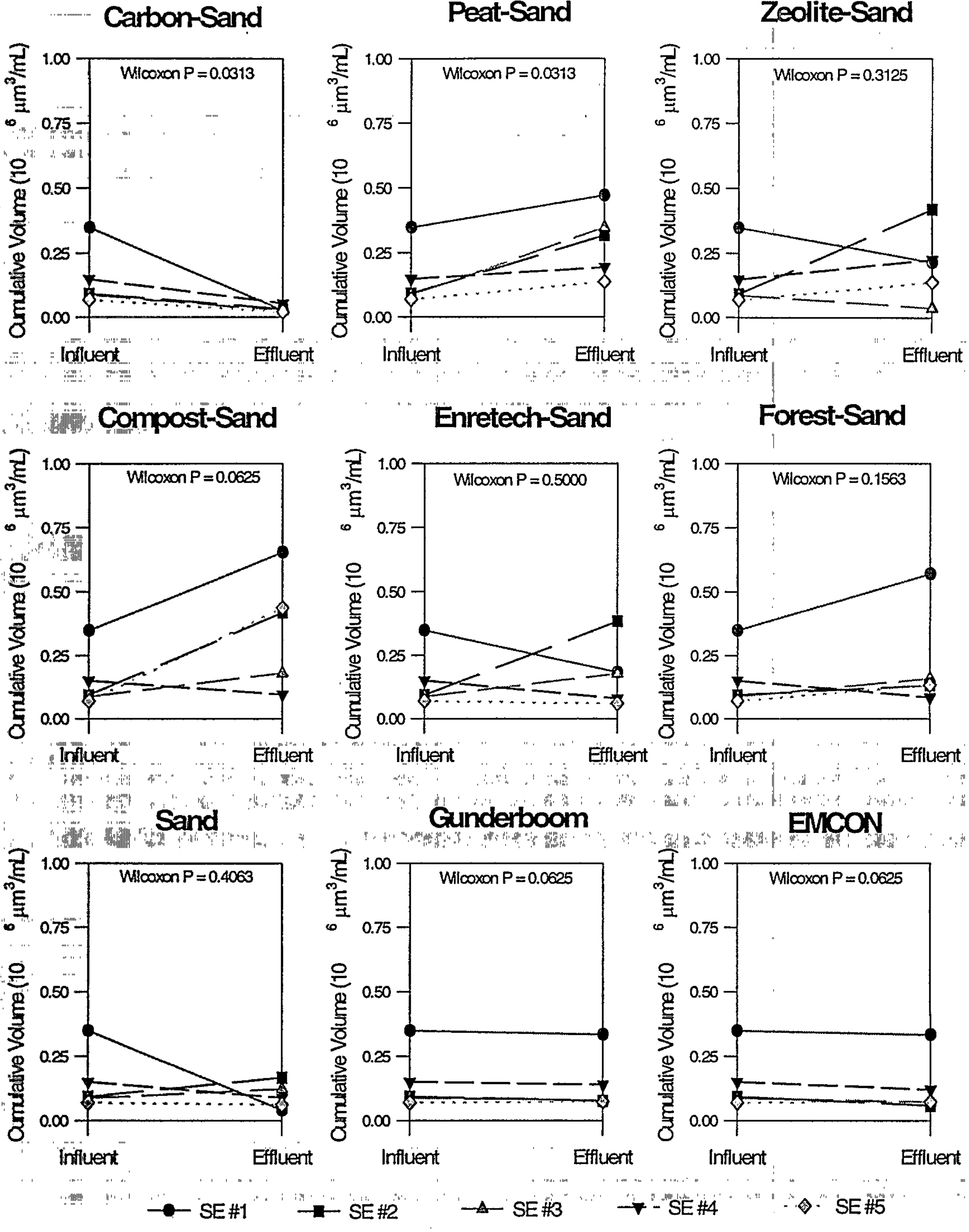
SAMPLE GROUP NAME	1 - 2 μm (μm^3/mL)			4 - 5 μm (μm^3/mL)			11 - 12.5 μm (μm^3/mL)			Cumulative (μm^3/mL)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	222,239	755,205	-240	4,736,682	1,350,697	71	347,726	570,654	-64	12,832,879	9,362,169	27
13.1 m	213,269	576,023	-170	163,202	2,266,125	-1,289	92,550	130,458	-41	1,415,822	8,824,918	-523
16.4 m	166,700	161,238	3	407,270	764,824	-88	86,165	157,989	-83	1,779,847	3,058,860	-72
20.6 m	129,761	359,147	-177	200,303	605,757	-202	149,220	82,890	44	1,952,688	2,882,181	-48
25.0 m	167,036	270,528	-62	274,109	513,365	-87	68,495	132,446	-93	1,533,127	1,742,452	-14
Sand												
8.5 m	222,239	274,579	-24	4,736,682	1,579,234	67	347,726	40,223	88	12,832,879	4,225,330	67
13.1 m	213,269	317,888	-49	163,202	1,835,608	-1,025	92,550	166,221	-80	1,415,822	6,253,006	-342
16.4 m	166,700	232,891	-40	407,270	775,133	-90	86,165	122,676	-42	1,779,847	2,918,964	-64
20.6 m	129,761	220,334	-70	200,303	591,264	-195	149,220	87,799	41	1,952,688	2,802,032	-43
25.0 m	167,036	427,173	-156	274,109	804,474	-193	68,495	61,360	10	1,533,127	3,624,544	-136
Gunderboom Fabric												
8.5 m	222,239	216,609	3	4,736,682	4,226,111	11	347,726	333,649	4	12,832,879	10,965,137	15
13.1 m	213,269	547,254	-157	163,202	300,601	-84	92,550	75,659	18	1,415,822	2,006,783	-42
16.4 m	166,700	115,276	31	407,270	290,130	29	86,165	78,077	9	1,779,847	1,388,839	22
20.6 m	129,761	132,008	-2	200,303	303,027	-51	149,220	138,439	7	1,952,688	1,933,883	1
25.0 m	167,036	149,815	10	274,109	252,261	8	68,495	72,640	-6	1,533,127	1,552,441	-1
EMCON Fabric												
8.5 m	222,239	276,601	-24	4,736,682	5,256,522	-11	347,726	333,022	4	12,832,879	13,119,485	-2
13.1 m	213,269	320,122	-50	163,202	196,991	-21	92,550	57,330	38	1,415,822	1,711,857	-21
16.4 m	166,700	133,909	20	407,270	438,059	-8	86,165	70,915	18	1,779,847	1,728,461	3
20.6 m	129,761	118,603	9	200,303	142,160	29	149,220	120,250	19	1,952,688	1,505,948	23
25.0 m	167,036	350,037	-110	274,109	304,148	-11	68,495	72,578	-6	1,533,127	2,854,571	-86



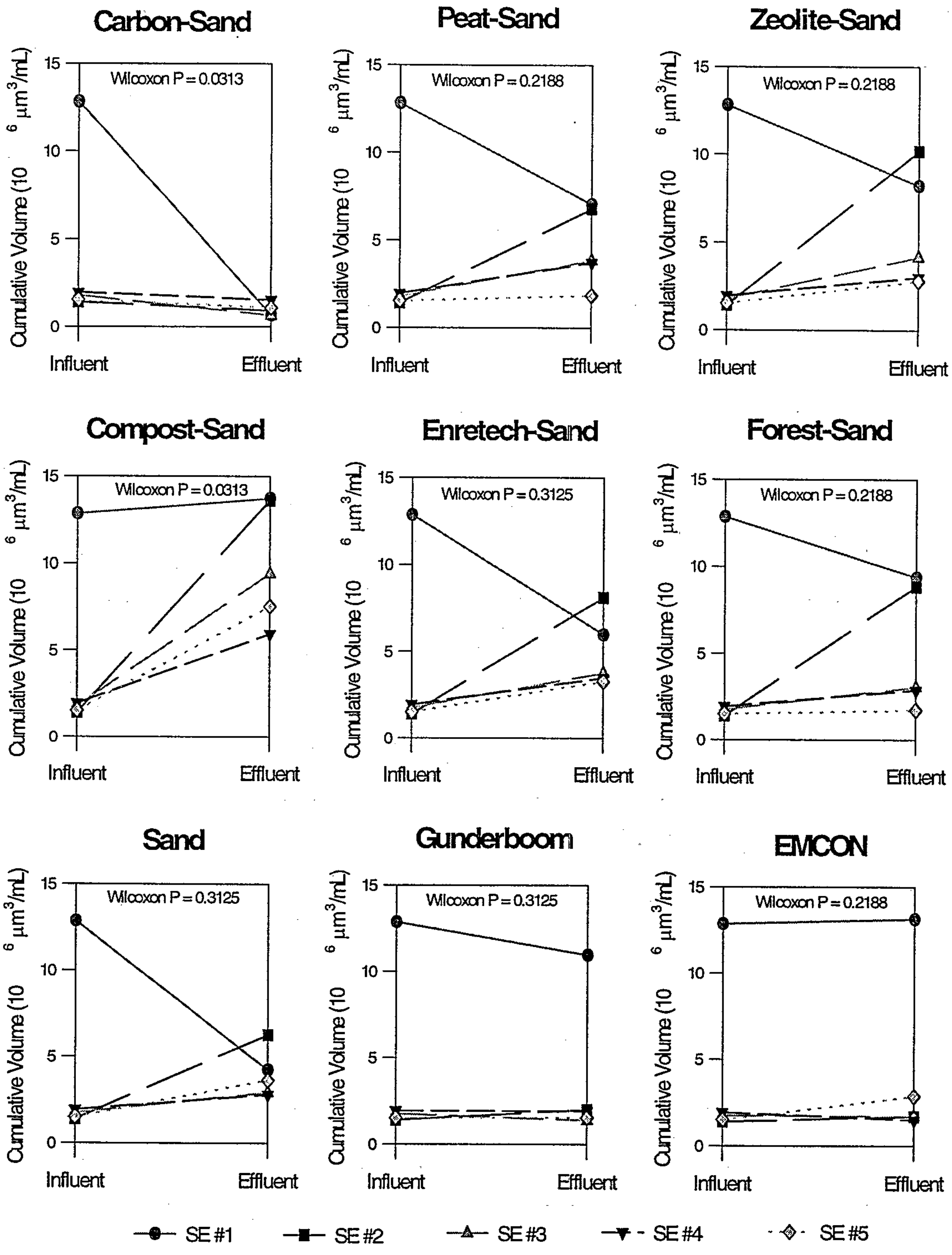
PARTICLE SIZE DISTRIBUTION: PreSettled Influent
(1 to 2 μm)



PARTICLE SIZE DISTRIBUTION: PreSettled Influent (4 to 5 µm)



PARTICLE SIZE DISTRIBUTION: PreSettled Influent (11 to 12.5 µm)



Carbon-Sand

Peat-Sand

Zeolite-Sand

Compost-Sand

Enretech-Sand

Forest-Sand

Sand

Gunderboom

EMCON

PARTICLE SIZE DISTRIBUTION: PreSettled Influent (1 to 128 µm)

PSD

FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

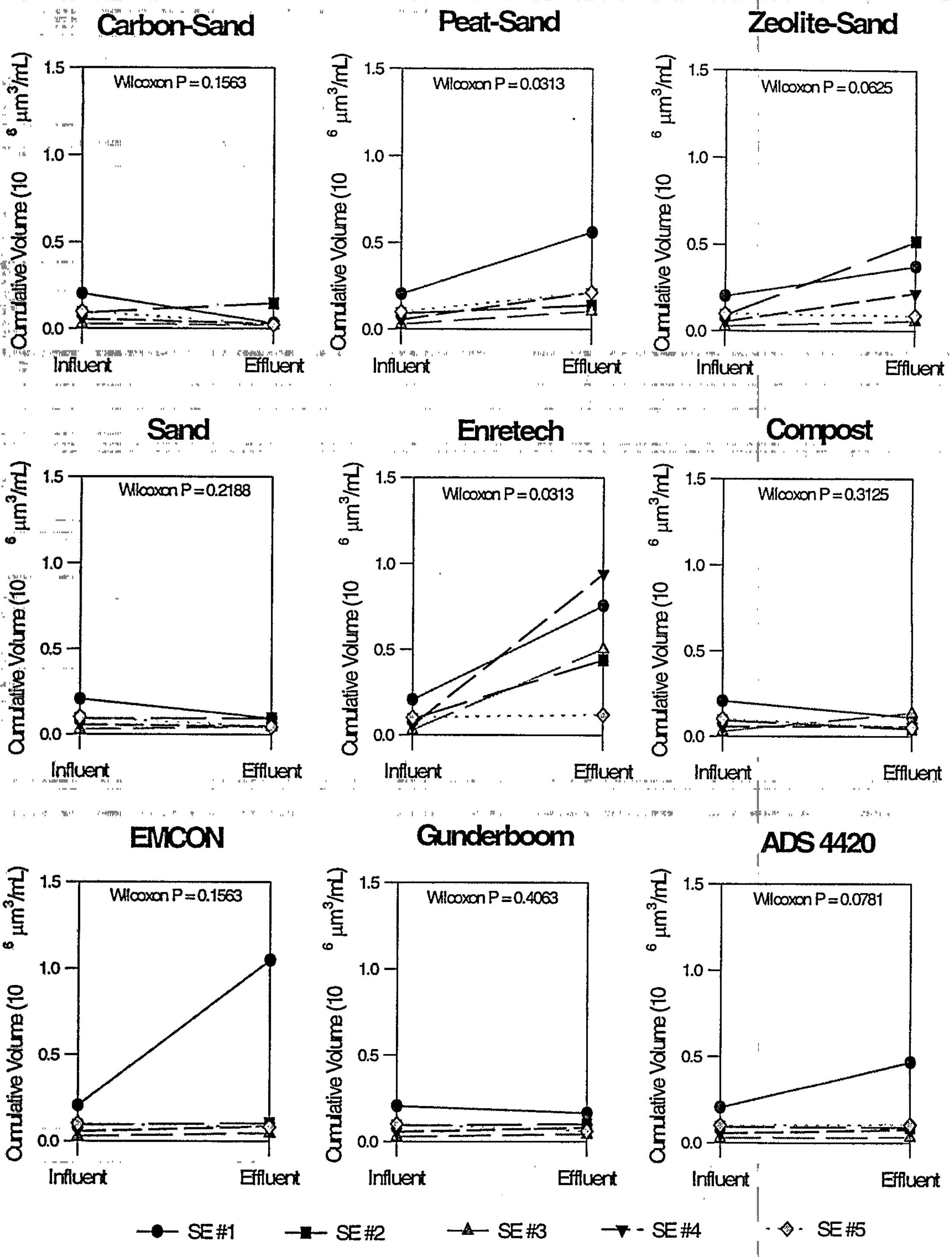
SAMPLE GROUP NAME	1 - 2 μm (μm^3/mL)			4 - 5 μm (μm^3/mL)			11 - 12.5 μm (μm^3/mL)			Cumulative (μm^3/mL)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
1.1 m	204,637	30,471	85	463,288	60,275	87	2,176,590	118,348	95	24,816,576	2,492,405	90
2.2 m	91,019	145,991	-60	135,325	228,820	-69	419,751	188,688	55	15,145,581	4,445,555	71
3.3 m	28,128	17,555	38	77,788	28,005	64	213,852	53,659	75	4,581,296	1,988,827	57
4.4 m	54,838	27,211	50	192,419	82,043	57	828,087	143,694	83	13,119,185	1,594,842	88
5.5 m	101,058	21,060	79	267,129	31,555	88	1,380,261	26,058	98	30,742,002	1,013,899	97
Peat-Sand												
1.1 m	204,637	561,094	-174	463,288	873,876	-89	2,176,590	1,202,570	45	24,816,576	15,800,901	36
2.2 m	91,019	140,474	-54	135,325	139,185	-3	419,751	328,529	22	15,145,581	4,169,260	72
3.3 m	28,128	106,042	-277	77,788	269,539	-247	213,852	301,129	-41	4,581,296	7,348,391	-60
4.4 m	54,838	215,414	-293	192,419	600,985	-212	828,087	1,312,237	-58	13,119,185	11,733,902	11
5.5 m	101,058	215,927	-114	267,129	519,587	-95	1,380,261	446,225	68	30,742,002	5,766,312	81
Zeolite-Sand												
1.1 m	204,637	376,740	-84	463,288	1,179,608	-155	2,176,590	698,168	68	24,816,576	10,957,558	56
2.2 m	91,019	250,492	-175	135,325	385,475	-185	419,751	65,807	84	15,145,581	4,205,814	72
3.3 m	28,128	56,753	-102	77,788	136,033	-75	213,852	197,676	8	4,581,296	3,463,733	24
4.4 m	54,838	220,648	-302	192,419	816,362	-324	828,087	361,225	56	13,119,185	6,768,128	48
5.5 m	101,058	88,956	12	267,129	191,512	28	1,380,261	188,315	86	30,742,002	2,738,344	91
Sand												
1.1 m	204,637	93,374	54	463,288	250,698	46	2,176,590	219,537	90	24,816,576	4,497,096	82
2.2 m	91,019	92,829	-2	135,325	83,450	38	419,751	21,108	95	15,145,581	2,731,588	82
3.3 m	28,128	44,209	-57	77,788	101,730	-31	213,852	42,597	80	4,581,296	5,293,040	-16
4.4 m	54,838	46,421	15	192,419	127,384	34	828,087	259,084	69	13,119,185	2,540,314	81
5.5 m	101,058	42,348	58	267,129	55,430	79	1,380,261	52,415	96	30,742,002	1,389,224	95
Enretech												
1.1 m	204,637	756,255	-270	463,288	1,110,004	-140	2,176,590	113,495	95	24,816,576	6,262,257	75
2.2 m	91,019	440,495	-384	135,325	630,242	-366	419,751	379,852	10	15,145,581	7,978,896	47
3.3 m	28,128	504,256	-1,693	77,788	902,637	-1,060	213,852	699,096	-227	4,581,296	12,031,468	-163
4.4 m	54,838	942,338	-1,618	192,419	1,342,823	-598	828,087	1,710,934	-107	13,119,185	19,378,620	-48
5.5 m	101,058	117,520	-16	267,129	209,106	22	1,380,261	323,951	77	30,742,002	3,560,360	88

PSD (Continued)

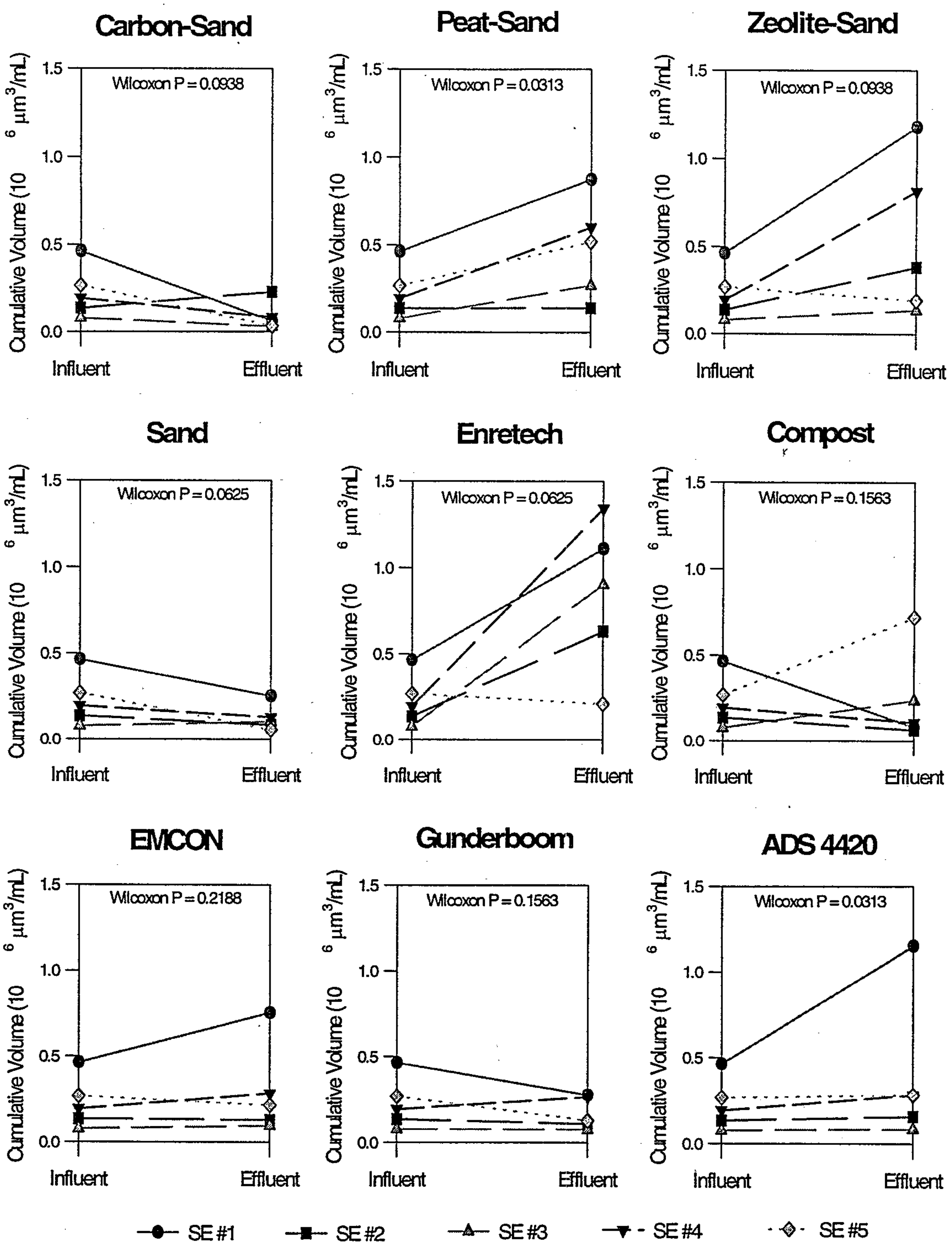
FILTRATION MEDIA EVALUATION: Unpretreated Influent

Summer 1994

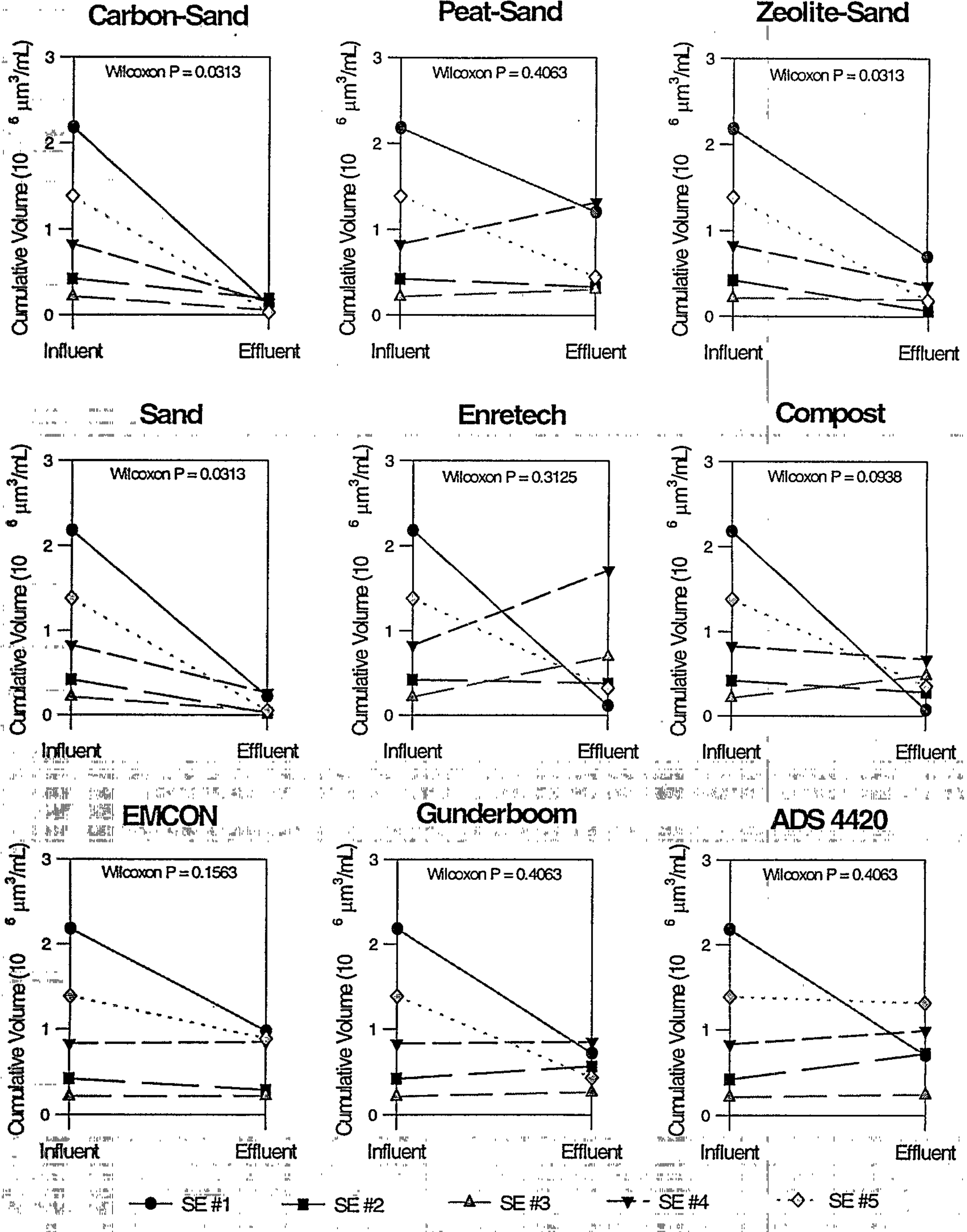
SAMPLE GROUP NAME	1 - 2 μm ($\mu m^3/mL$)			4 - 5 μm ($\mu m^3/mL$)			11 - 12.5 μm ($\mu m^3/mL$)			Cumulative ($\mu m^3/mL$)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost												
1.1 m	204,637	108,191	47	463,288	80,784	83	2,176,590	70,504	97	24,816,576	3,943,957	84
2.2 m	91,019	41,056	55	135,325	65,094	52	419,751	280,891	33	15,145,581	7,107,894	53
3.3 m	28,128	133,921	-376	77,788	235,535	-203	213,852	482,226	-125	4,581,296	8,829,422	-93
4.4 m	54,838	56,897	-4	192,419	107,745	44	828,087	674,869	19	13,119,185	11,262,428	14
5.5 m	101,058	49,284	51	267,129	71,776	73	1,380,261	354,263	74	30,742,002	6,304,884	79
EMCON Fabric												
1.1 m	204,637	1,047,003	-412	463,288	752,259	-62	2,176,590	977,812	55	24,816,576	12,861,128	48
2.2 m	91,019	103,707	-14	135,325	129,283	4	419,751	288,126	31	15,145,581	6,126,888	60
3.3 m	28,128	45,546	-62	77,788	95,572	-23	213,852	217,845	-2	4,581,296	4,406,809	4
4.4 m	54,838	83,398	-52	192,419	282,403	-47	828,087	848,605	-2	13,119,185	10,055,400	23
5.5 m	101,058	79,521	21	267,129	213,976	20	1,380,261	889,280	36	30,742,002	13,838,937	55
Gunderboom Fabric												
1.1 m	204,637	165,200	19	463,288	274,476	41	2,176,590	716,957	67	24,816,576	11,809,218	52
2.2 m	91,019	99,585	-9	135,325	108,188	20	419,751	565,257	-35	15,145,581	8,230,659	46
3.3 m	28,128	42,716	-52	77,788	75,449	3	213,852	265,482	-24	4,581,296	3,973,314	13
4.4 m	54,838	79,203	-44	192,419	264,455	-37	828,087	851,174	-3	13,119,185	10,177,487	22
5.5 m	101,058	59,174	41	267,129	128,205	52	1,380,261	433,916	69	30,742,002	7,408,825	76
ADS 4420 Fabric												
1.1 m	204,637	465,480	-127	463,288	1,152,067	-149	2,176,590	698,168	68	24,816,576	10,957,561	56
2.2 m	91,019	88,115	3	135,325	156,971	-16	419,751	718,360	-71	15,145,581	13,689,703	10
3.3 m	28,128	33,416	-19	77,788	84,836	-9	213,852	242,394	-13	4,581,296	4,523,369	1
4.4 m	54,838	76,272	-39	192,419	281,764	-46	828,087	990,850	-20	13,119,185	17,360,162	-32
5.5 m	101,058	103,977	-3	267,129	281,717	-5	1,380,261	1,307,107	5	30,742,002	24,720,218	20



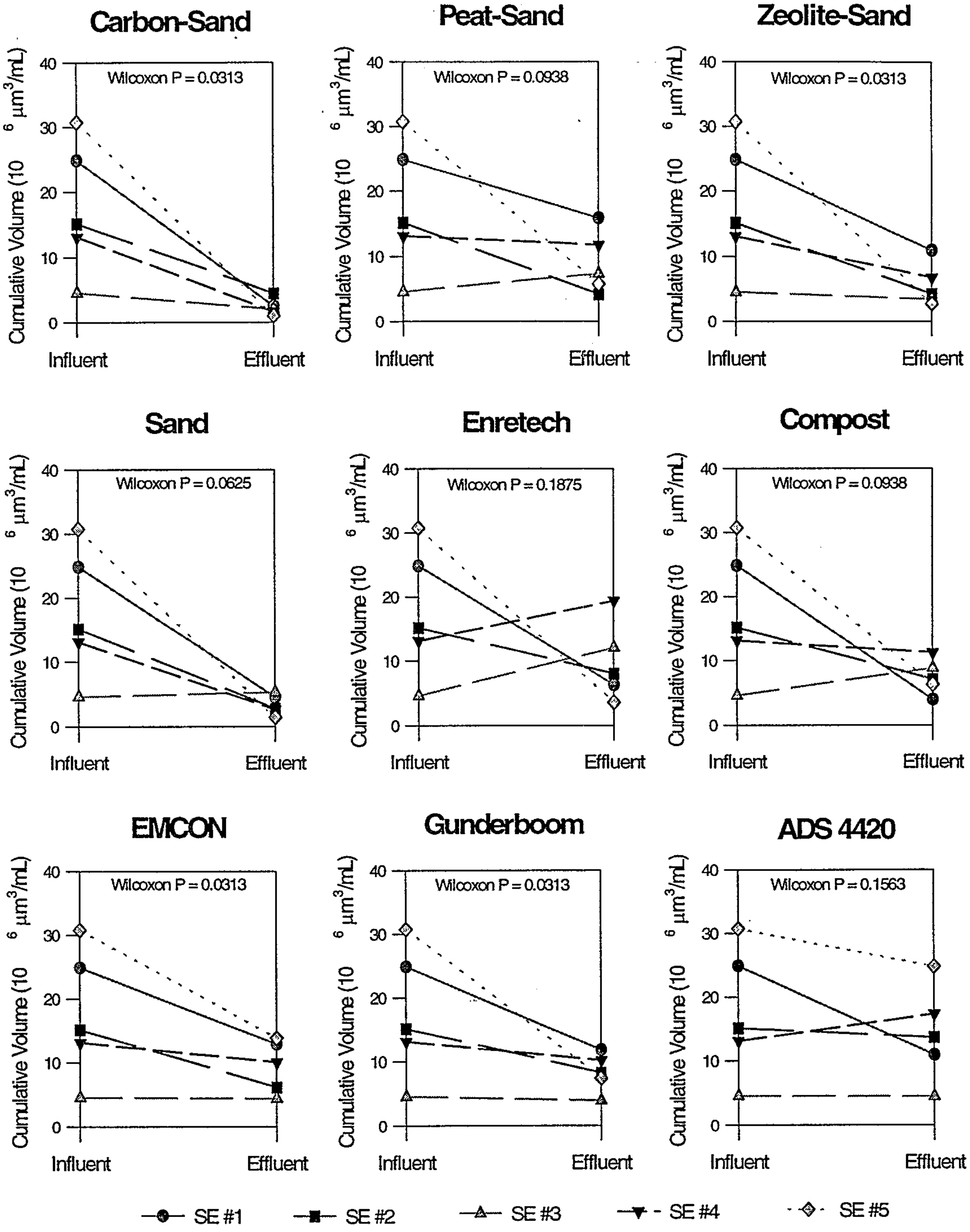
PARTICLE SIZE DISTRIBUTION: Unpretreated Influent (1 to 2 μm)



PARTICLE SIZE DISTRIBUTION: Unpretreated Influent
(4 to 5 µm)



PARTICLE SIZE DISTRIBUTION: Unpretreated Influent (11 to 12 µm)



PARTICLE SIZE DISTRIBUTION: Unpretreated Influent (1 to 128 μm)

Appendix G:
Metals

Zinc
Copper

ZINC

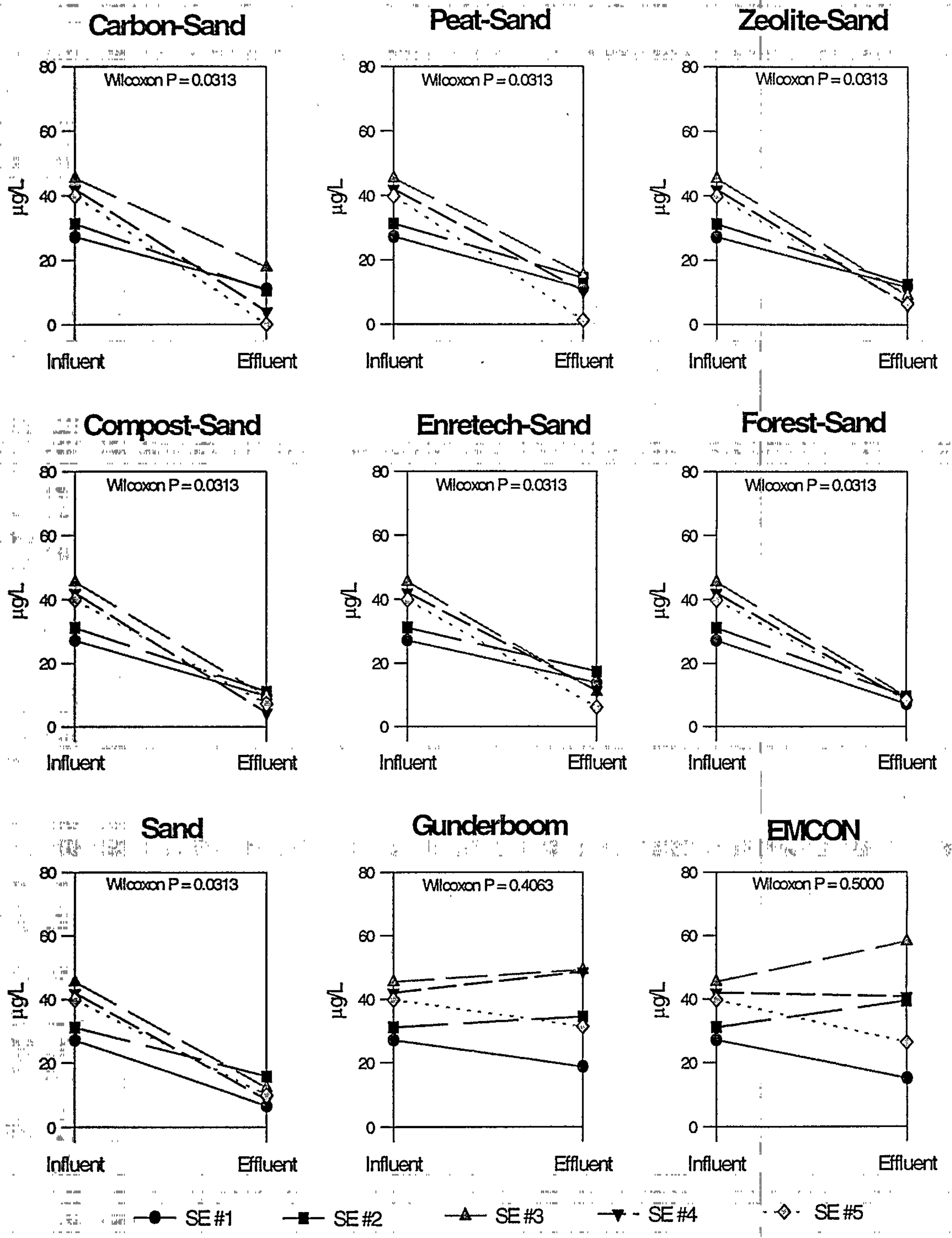
FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Unfiltered Fraction (µg/L)			Filtered Fraction (µg/L)			Particulate Fraction (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
8.5 m	27.2	10.9	60	17.8	9.3	48	9.4	1.6	83
13.1 m	31.2	10.4	67	29.5	13.5	54	1.7	0.0	100
16.4 m	45.4	17.7	61	23.3	13.5	42	22.1	4.2	81
20.6 m	42.0	3.9	91	26.7	0.0	100	15.3	3.9	75
25.0 m	39.8	0.0	100	30.7	32.1	-5	9.1	0.0	100
Peat-Sand									
8.5 m	27.2	11.0	60	17.8	16.1	10	9.4	0.0	100
13.1 m	31.2	14.3	54	29.5	12.4	58	1.7	1.9	-12
16.4 m	45.4	15.3	66	23.3	6.3	73	22.1	9.0	59
20.6 m	42.0	10.1	76	26.7	13.2	51	15.3	0.0	100
25.0 m	39.8	1.2	97	30.7	0.0	100	9.1	1.2	87
Zeolite-Sand									
8.5 m	27.2	11.6	57	17.8	4.0	78	9.4	7.6	19
13.1 m	31.2	12.5	60	29.5	13.7	54	1.7	0.0	100
16.4 m	45.4	8.9	80	23.3	17.7	24	22.1	0.0	100
20.6 m	42.0	5.9	86	26.7	0.0	100	15.3	5.9	61
25.0 m	39.8	6.4	84	30.7	14.2	54	9.1	0.0	100
Compost-Sand									
8.5 m	27.2	9.6	65	17.8	7.8	56	9.4	1.8	81
13.1 m	31.2	11.0	65	29.5	4.8	84	1.7	6.2	-265
16.4 m	45.4	9.5	79	23.3	7.2	69	22.1	2.3	90
20.6 m	42.0	4.3	90	26.7	0.0	100	15.3	4.3	72
25.0 m	39.8	7.1	82	30.7	0.0	100	9.1	7.1	22
Enretech-Sand									
8.5 m	27.2	13.7	50	17.8	5.8	67	9.4	7.9	16
13.1 m	31.2	17.3	45	29.5	6.7	77	1.7	10.6	-524
16.4 m	45.4	10.9	76	23.3	7.5	68	22.1	3.4	85
20.6 m	42.0	11.3	73	26.7	0.0	100	15.3	11.3	26
25.0 m	39.8	6.0	85	30.7	8.0	74	9.1	0.0	100

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

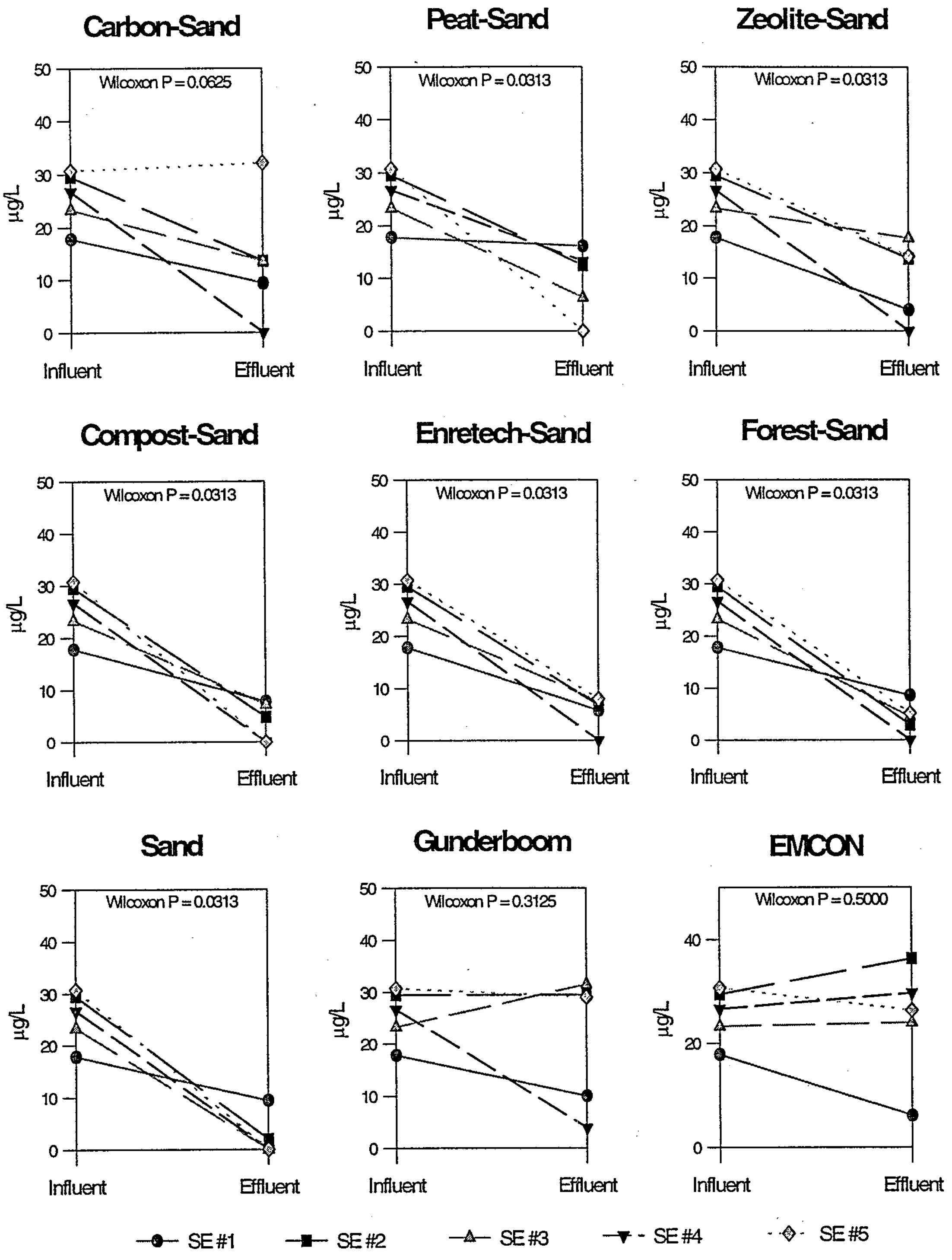
ZINC (Continued)

SAMPLE GROUP NAME	Unfiltered Fraction (µg/L)			Filtered Fraction (µg/L)			Particulate Fraction (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand									
8.5 m	27.2	7.1	74	17.8	8.6	52	9.4	0.0	100
13.1 m	31.2	9.5	70	29.5	2.9	90	1.7	6.6	-288
16.4 m	45.4	9.4	79	23.3	4.5	81	22.1	4.9	78
20.6 m	42.0	8.2	80	26.7	0.0	100	15.3	8.2	46
25.0 m	39.8	8.2	79	30.7	0.7	98	9.1	7.5	18
Sand									
8.5 m	27.2	6.6	76	17.8	9.4	47	9.4	0.0	100
13.1 m	31.2	15.7	50	29.5	1.9	94	1.7	13.8	-712
16.4 m	45.4	12.2	73	23.3	0.0	100	22.1	12.2	45
20.6 m	42.0	8.5	80	26.7	0.0	100	15.3	8.5	44
25.0 m	39.8	9.9	75	30.7	0.0	100	9.1	9.9	-9
Gunderboom Fabric									
8.5 m	27.2	18.7	31	17.8	10.0	44	9.4	8.7	7
13.1 m	31.2	34.5	-11	29.5	29.5	0	1.7	5.0	-194
16.4 m	45.4	49.2	-8	23.3	31.5	-35	22.1	17.7	20
20.6 m	42.0	48.6	-16	26.7	3.8	86	15.3	44.8	-193
25.0 m	39.8	31.4	21	30.7	29.0	6	9.1	2.4	74
EMCON Fabric									
8.5 m	27.2	15.1	44	17.8	6.1	66	9.4	9.0	4
13.1 m	31.2	39.5	-27	29.5	36.3	-23	1.7	3.2	-88
16.4 m	45.4	58.2	-28	23.3	24.0	-3	22.1	34.2	-55
20.6 m	42.0	40.8	3	26.7	29.7	-11	15.3	11.1	27
25.0 m	39.8	26.5	33	30.7	26.4	14	9.1	0.1	99



ZINC: PreSettled Influent

Unfiltered Fraction



ZINC: PreSettled Influent
Filtered Fraction

COPPER

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

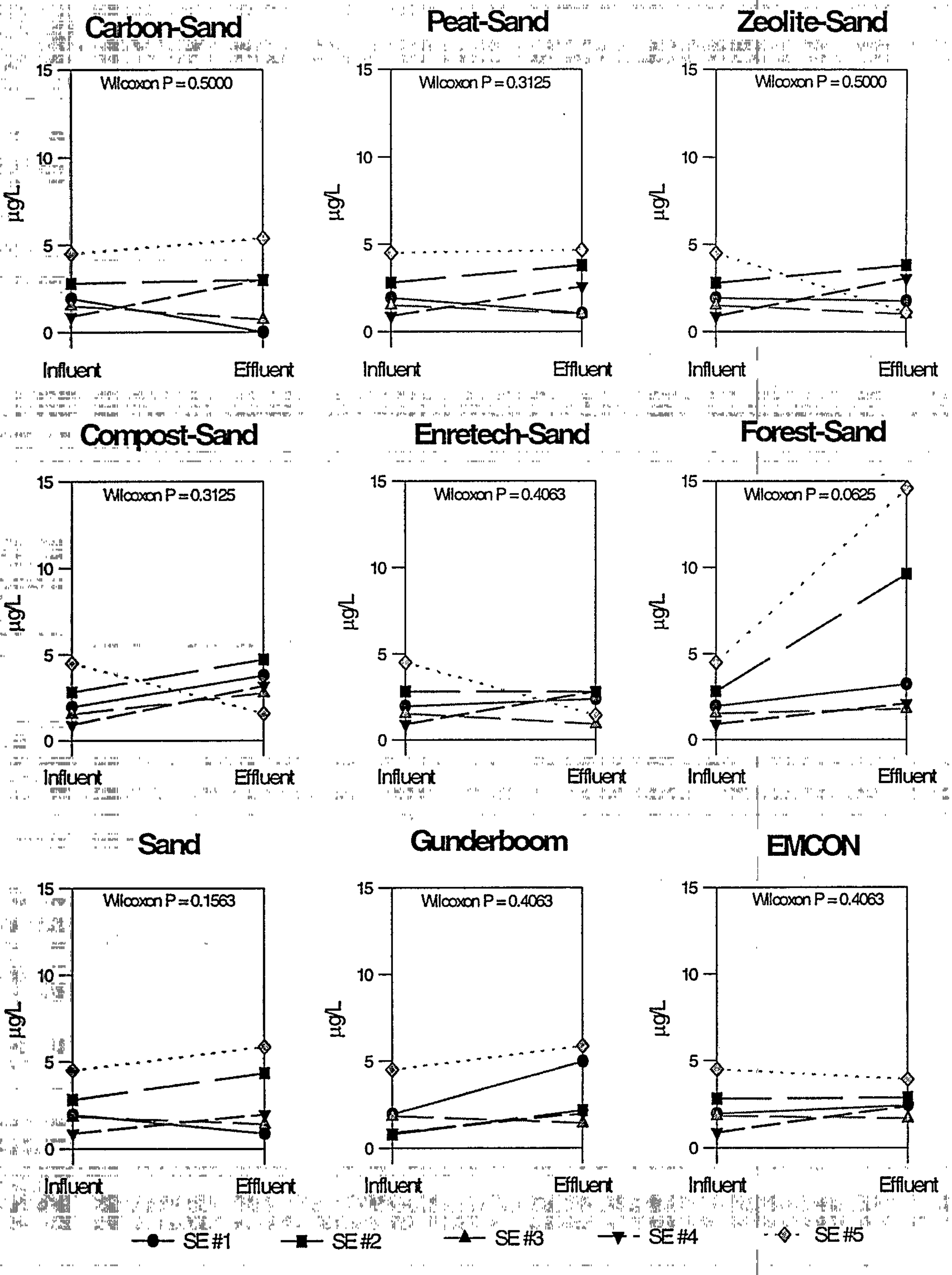
SAMPLE GROUP NAME	Unfiltered Fraction (µg/L)			Filtered Fraction (µg/L)			Particulate Fraction (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
8.5 m	1.94	ND	100	0.58	1.54	-163	1.35	ND	100
13.1 m	2.81	2.99	-7	3.75	6.33	-69	ND	ND	N/A
16.4 m	1.51	0.70	54	3.10	0.66	79	ND	0.04	N/A
20.6 m	0.90	3.03	-238	0.95	0.92	3	ND	2.11	N/A
25.0 m	4.50	5.36	-19	2.61	0.77	70	1.89	4.58	-143
Peat-Sand									
8.5 m	1.94	1.05	46	0.58	4.73	-710	1.35	ND	100
13.1 m	2.81	3.80	-35	3.75	3.33	11	ND	0.48	N/A
16.4 m	1.51	1.01	33	3.10	ND	100	ND	1.01	N/A
20.6 m	0.90	2.59	-189	0.95	3.88	-310	ND	ND	N/A
25.0 m	4.50	4.67	-4	2.61	1.89	28	1.89	2.78	-47
Zeolite-Sand									
8.5 m	1.94	1.79	8	0.58	0.81	-39	1.35	0.98	28
13.1 m	2.81	3.84	-37	3.75	2.63	30	ND	1.21	N/A
16.4 m	1.51	1.01	33	3.10	0.87	72	ND	0.14	N/A
20.6 m	0.90	3.10	-246	0.95	1.42	-50	ND	1.68	N/A
25.0 m	4.50	1.13	75	2.61	2.48	5	1.89	ND	100
Compost-Sand									
8.5 m	1.94	3.78	-95	0.58	1.14	-95	1.35	2.64	-95
13.1 m	2.81	4.70	-67	3.75	2.79	26	ND	1.91	N/A
16.4 m	1.51	2.75	-83	3.10	3.49	-13	ND	ND	N/A
20.6 m	0.90	3.17	-254	0.95	2.45	-159	ND	0.72	N/A
25.0 m	4.50	1.55	66	2.61	2.83	-8	1.89	ND	100
Enretech-Sand									
8.5 m	1.94	2.35	-21	0.58	3.17	-443	1.35	ND	100
13.1 m	2.81	2.77	1	3.75	5.03	-34	ND	ND	N/A
16.4 m	1.51	0.89	41	3.10	2.98	4	ND	ND	N/A
20.6 m	0.90	2.80	-213	0.95	0.71	25	ND	2.09	N/A
25.0 m	4.50	1.40	69	2.61	1.07	59	1.89	0.33	82

FILTRATION MEDIA EVALUATION: PreSettled Influent

Fall 1995

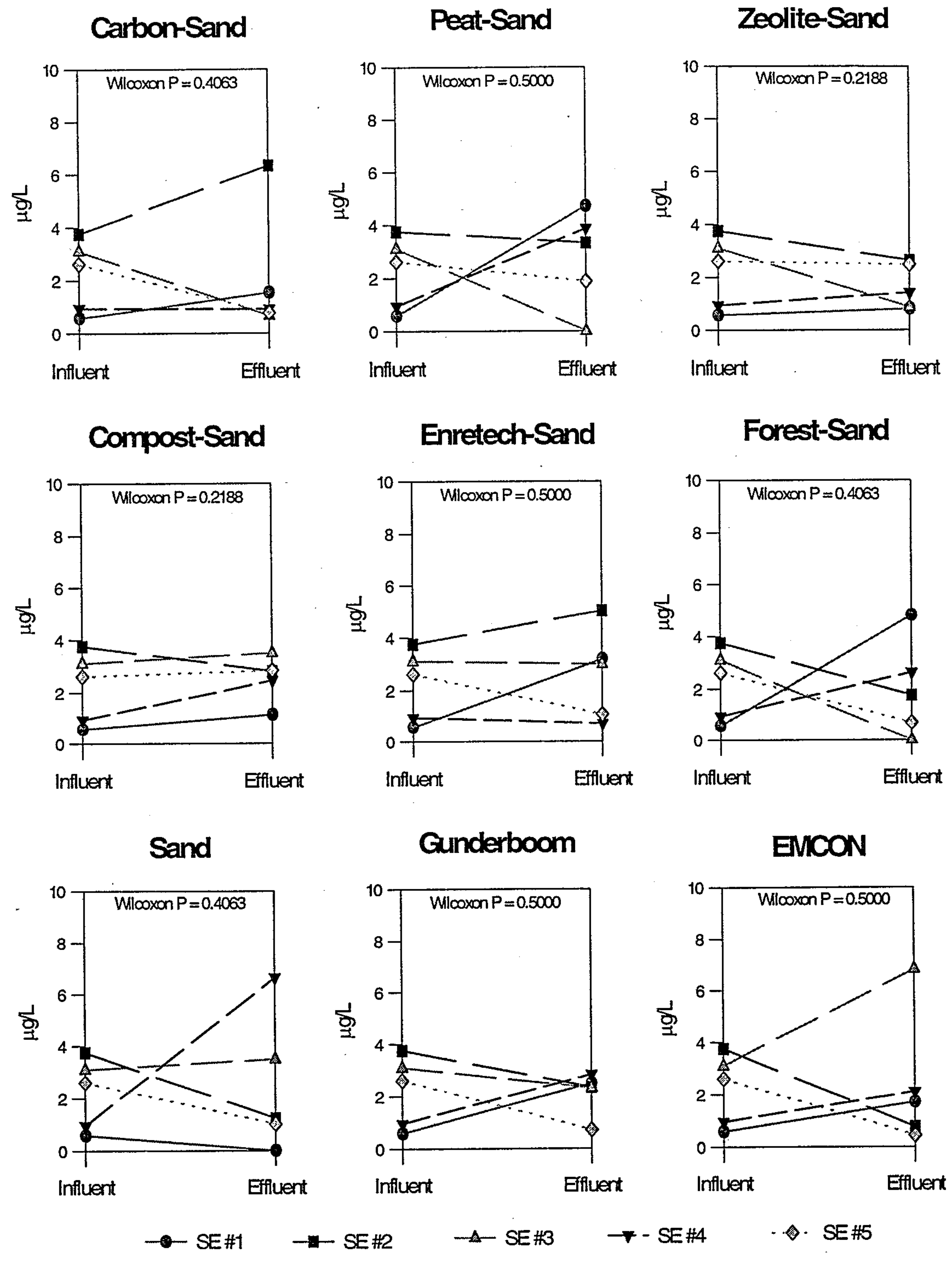
COPPER (Continued)

SAMPLE GROUP NAME	Unfiltered Fraction (µg/L)			Filtered Fraction (µg/L)			Particulate Fraction (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand									
8.5 m	1.94	3.24	-67	0.58	4.82	-725	1.35	ND	100
13.1 m	2.81	9.64	-243	3.75	1.76	53	ND	7.88	N/A
16.4 m	1.81	1.77	2	3.10	ND	100	ND	1.77	N/A
20.6 m	0.90	2.09	-133	0.95	2.63	-177	ND	ND	N/A
25.0 m	4.50	14.58	-224	2.61	0.70	73	1.89	13.88	-635
Sand									
8.5 m	1.94	0.90	53	0.58	ND	100	1.35	0.90	33
13.1 m	2.81	4.33	-54	3.75	1.22	67	ND	3.11	N/A
16.4 m	1.81	1.41	22	3.10	3.49	-13	ND	ND	N/A
20.6 m	0.90	1.95	-118	0.95	6.63	-600	ND	ND	N/A
25.0 m	4.50	5.85	-30	2.61	1.00	62	1.89	4.84	-157
Gunderboom Fabric									
8.5 m	1.94	4.97	-156	0.58	2.50	-328	1.35	2.47	-82
13.1 m	2.81	2.14	24	3.75	2.34	37	ND	ND	N/A
16.4 m	1.81	1.51	16	3.10	2.31	25	ND	ND	N/A
20.6 m	0.90	5.16	-476	0.95	2.84	-199	ND	2.33	N/A
25.0 m	4.50	2.75	39	2.61	0.70	73	1.89	2.05	-9
EMCON Fabric									
8.5 m	1.94	2.44	-26	0.58	1.71	-193	1.35	0.73	46
13.1 m	2.81	2.87	-2	3.75	0.75	80	ND	2.12	N/A
16.4 m	1.81	1.67	8	3.10	6.82	-120	ND	ND	N/A
20.6 m	0.90	2.38	-165	0.95	2.11	-122	ND	0.27	N/A
25.0 m	4.50	3.92	13	2.61	0.44	83	1.89	3.48	-84



COPPER: PreSettled Influent

Unfiltered Fraction



COPPER: PreSettled Influent
Filtered Fraction

Appendix H:

Chemical Oxygen Demand
Semi-Volatile Organics
Pesticides

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

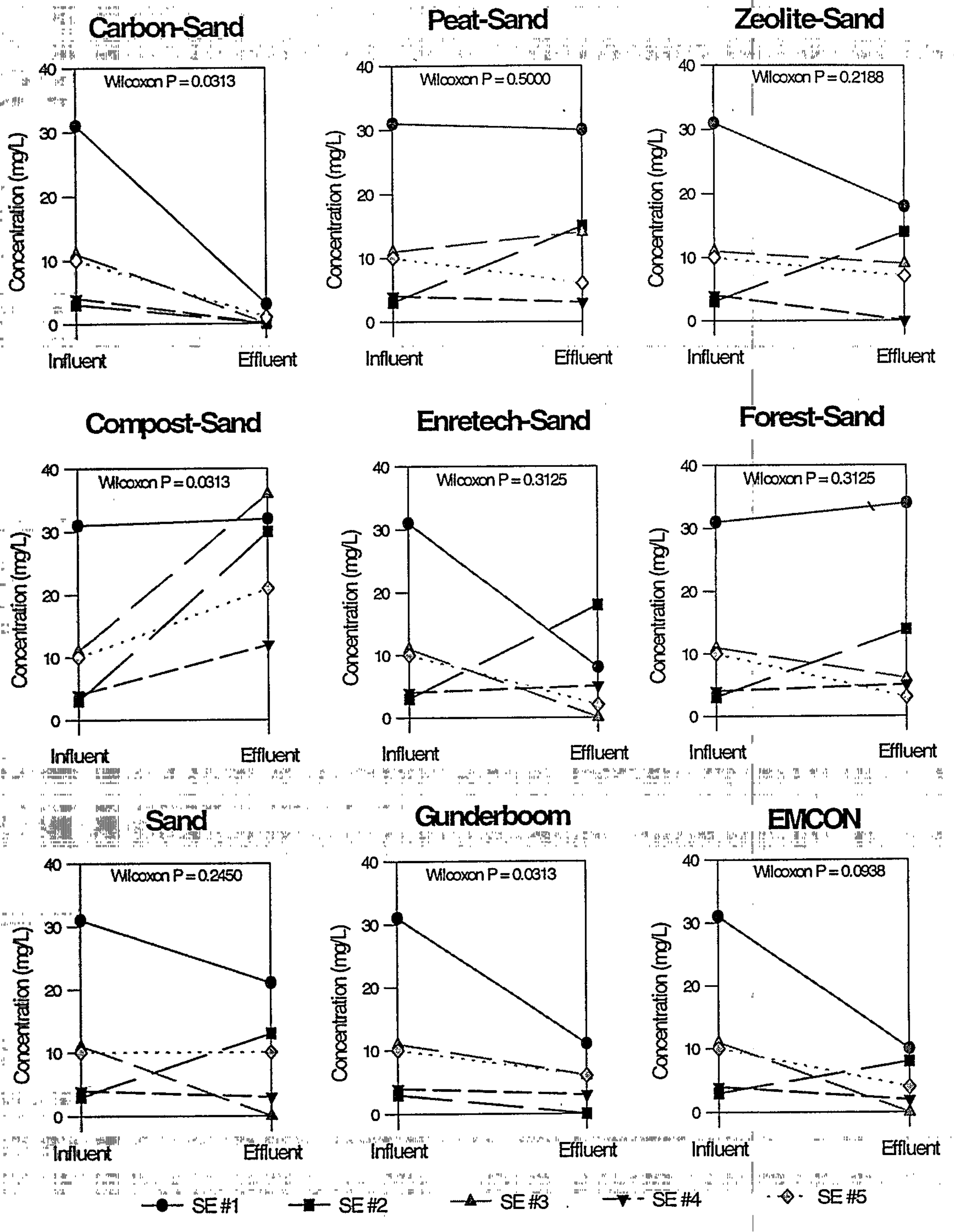
COD

SAMPLE GROUP NAME	Unfiltered Fraction (mg/L)			Filtered Fraction (mg/L)			Particulate Fraction (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
8.5 m	31	3	90	21	16	24	10	5	50
13.1 m	3	0	100	4	0	100	<0	4	N/A
16.4 m	11	0	100	10	0	100	11	10	9
20.6 m	4	0	100	7	0	100	<0	7	N/A
25.0 m	10	1	90	4	0	100	6	4	33
Peat-Sand									
8.5 m	31	30	3	21	28	-33	10	<0	100
13.1 m	3	15	-400	4	21	-425	<0	<0	N/A
16.4 m	11	14	-27	10	8	20	1	2	-100
20.6 m	4	3	25	7	0	100	<0	7	N/A
25.0 m	10	6	40	4	5	-25	6	<0	100
Zeolite-Sand									
8.5 m	31	18	42	21	17	19	10	4	60
13.1 m	3	14	-367	4	19	-375	<0	<0	N/A
16.4 m	11	9	18	10	0	100	1	10	-900
20.6 m	4	0	100	7	0	100	<0	7	N/A
25.0 m	10	7	30	4	6	-50	6	<0	100
Compost-Sand									
8.5 m	31	32	-3	21	34	-62	10	<0	100
13.1 m	3	30	-900	4	32	-700	<0	<0	N/A
16.4 m	11	36	-227	10	14	-40	1	<0	100
20.6 m	4	12	-200	7	8	-14	<0	<0	N/A
25.0 m	10	21	-110	4	10	-150	6	<0	100
Enretech-Sand									
8.5 m	31	8	74	21	15	29	10	6	40
13.1 m	3	18	-500	4	16	-300	<0	<0	N/A
16.4 m	11	0	100	10	0	100	1	10	-900
20.6 m	4	5	-25	7	0	100	<0	7	N/A
25.0 m	10	2	80	4	0	100	6	4	33

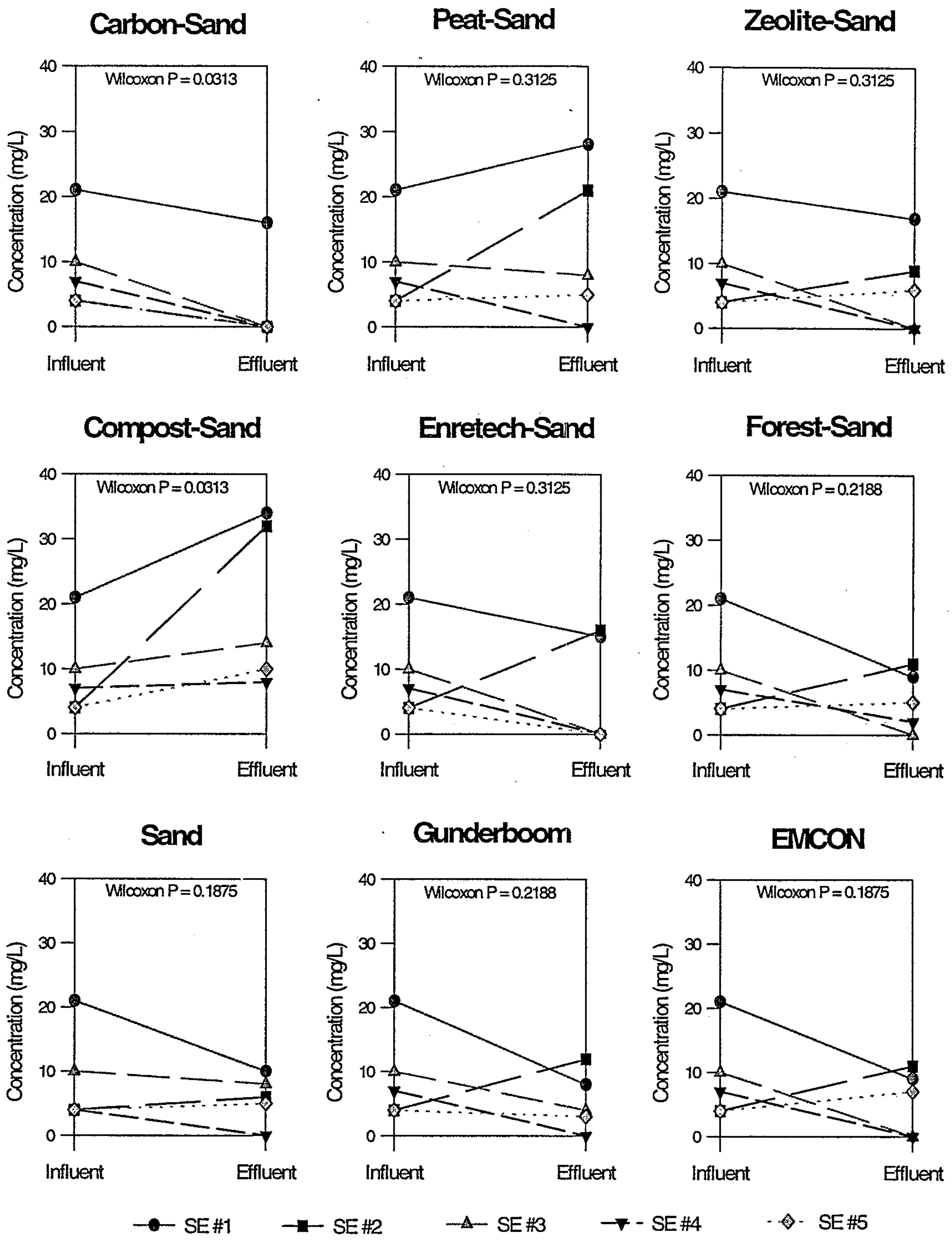
FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

COD (Continued)

SAMPLE GROUP NAME	Unfiltered Fraction (mg/L)			Filtered Fraction (mg/L)			Particulate Fraction (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand									
8.5 m	31	34	-10	21	9	57	10	12	-20
13.1 m	3	14	-367	4	11	-175	<0	<0	N/A
16.4 m	11	6	45	10	0	100	1	10	-900
20.6 m	4	5	-25	7	2	71	<0	5	N/A
25.0 m	10	3	70	4	5	-25	6	<0	100
Sand									
8.5 m	31	21	32	21	10	52	10	11	-10
13.1 m	3	13	-333	4	6	-50	<0	<0	N/A
16.4 m	11	0	100	10	8	20	1	2	-100
20.6 m	4	3	25	7	0	100	<0	7	N/A
25.0 m	10	10	0	4	5	-25	6	<0	100
Gunderboom Fabric									
8.5 m	31	11	65	21	8	62	10	13	-30
13.1 m	3	0	100	4	12	-200	<0	<0	N/A
16.4 m	11	6	45	10	4	60	1	6	-500
20.6 m	4	3	25	7	0	100	<0	7	N/A
25.0 m	10	6	40	4	3	25	6	1	83
EMCON Fabric									
8.5 m	31	10	68	21	9	57	10	12	-20
13.1 m	3	8	-167	4	11	-175	<0	<0	N/A
16.4 m	11	0	100	10	0	100	1	10	-900
20.6 m	4	2	50	7	0	100	<0	7	N/A
25.0 m	10	4	60	4	7	-75	6	<0	100



CHEMICAL OXYGEN DEMAND: PreSettled Influent
Unfiltered Fraction



CHEMICAL OXYGEN DEMAND: PreSettled Influent
Filtered Fraction

COD

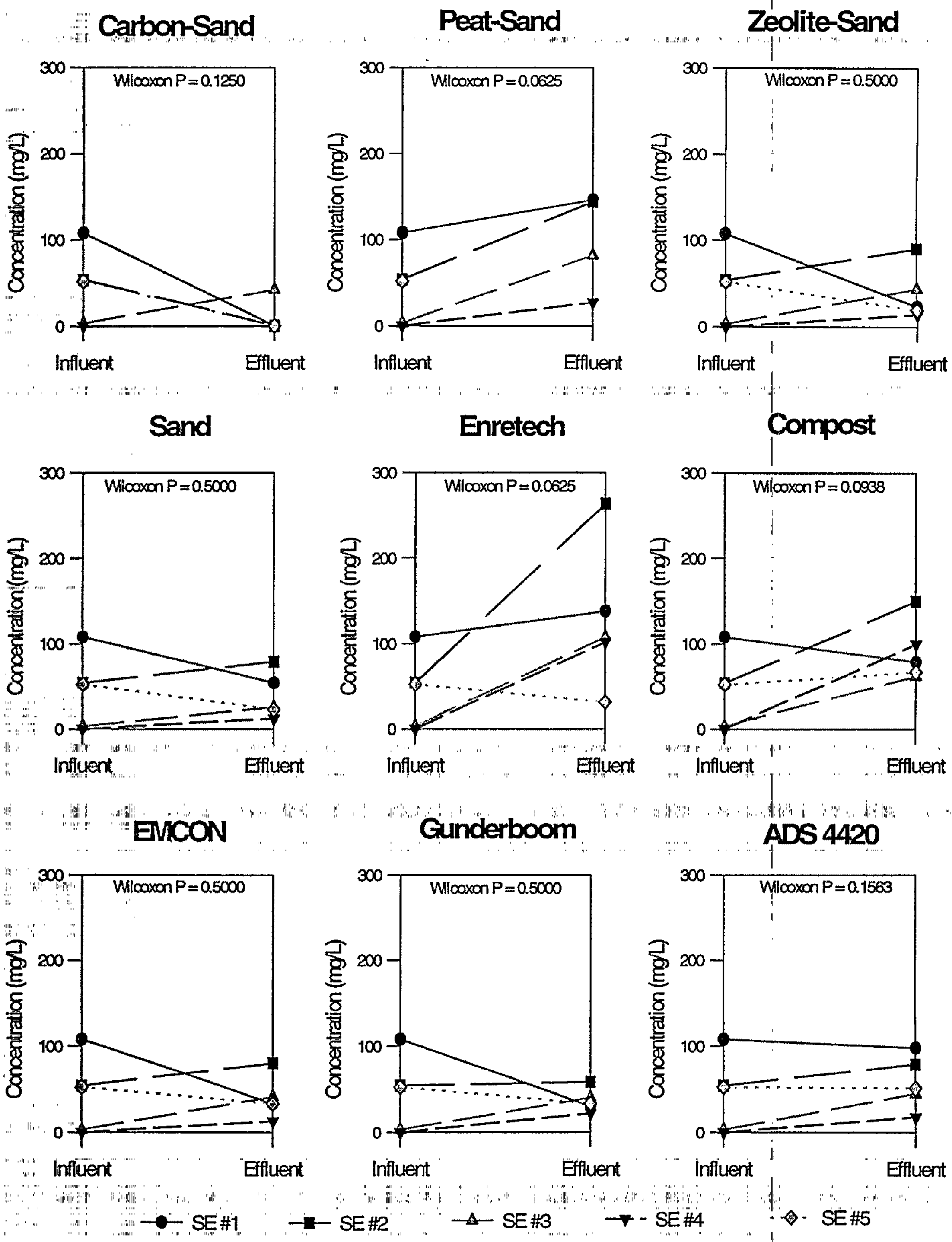
FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

SAMPLE GROUP NAME	Unfiltered Fraction (mg/L)			Filtered Fraction (mg/L)			Particulate Fraction (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand									
1.1 m	108	0	100	21	0	100	87	0	100
2.2 m	54	0	100	34	0	100	20	0	100
3.3 m	3	42	-1300	9	0	100	0	0	N/A
4.4 m	0	0	N/A	2	4	-100	0	0	N/A
5.5 m	52	0	100	16	1	94	36	0	100
Peat-Sand									
1.1 m	108	146	-35	21	49	-133	87	97	-11
2.2 m	54	144	-167	34	56	-65	20	88	-340
3.3 m	3	82	-2633	9	42	-367	0	40	N/A
4.4 m	0	27	N/A	2	26	-1200	0	1	N/A
5.5 m	52	broken	N/A	16	34	-113	36	0	100
Zeolite-Sand									
1.1 m	108	23	79	21	0	100	87	23	74
2.2 m	54	91	-69	34	15	56	20	76	-280
3.3 m	3	44	-1367	9	7	22	0	37	N/A
4.4 m	0	14	N/A	2	5	-150	0	9	N/A
5.5 m	52	19	63	16	23	-44	36	0	100
Sand									
1.1 m	108	54	50	21	49	-133	87	5	94
2.2 m	54	79	-46	34	56	-65	20	23	-15
3.3 m	3	25	-733	9	20	-122	0	5	N/A
4.4 m	0	12	N/A	2	0	100	0	12	N/A
5.5 m	52	22	58	16	21	-31	36	1	97
Enretech									
1.1 m	108	138	-28	21	111	-429	87	27	69
2.2 m	54	264	-389	34	125	-268	20	139	-595
3.3 m	3	108	-3500	9		N/A	0	108	N/A
4.4 m	0	102	N/A	2	59	-2850	0	43	N/A
5.5 m	52	31	40	16	36	-125	36	0	100

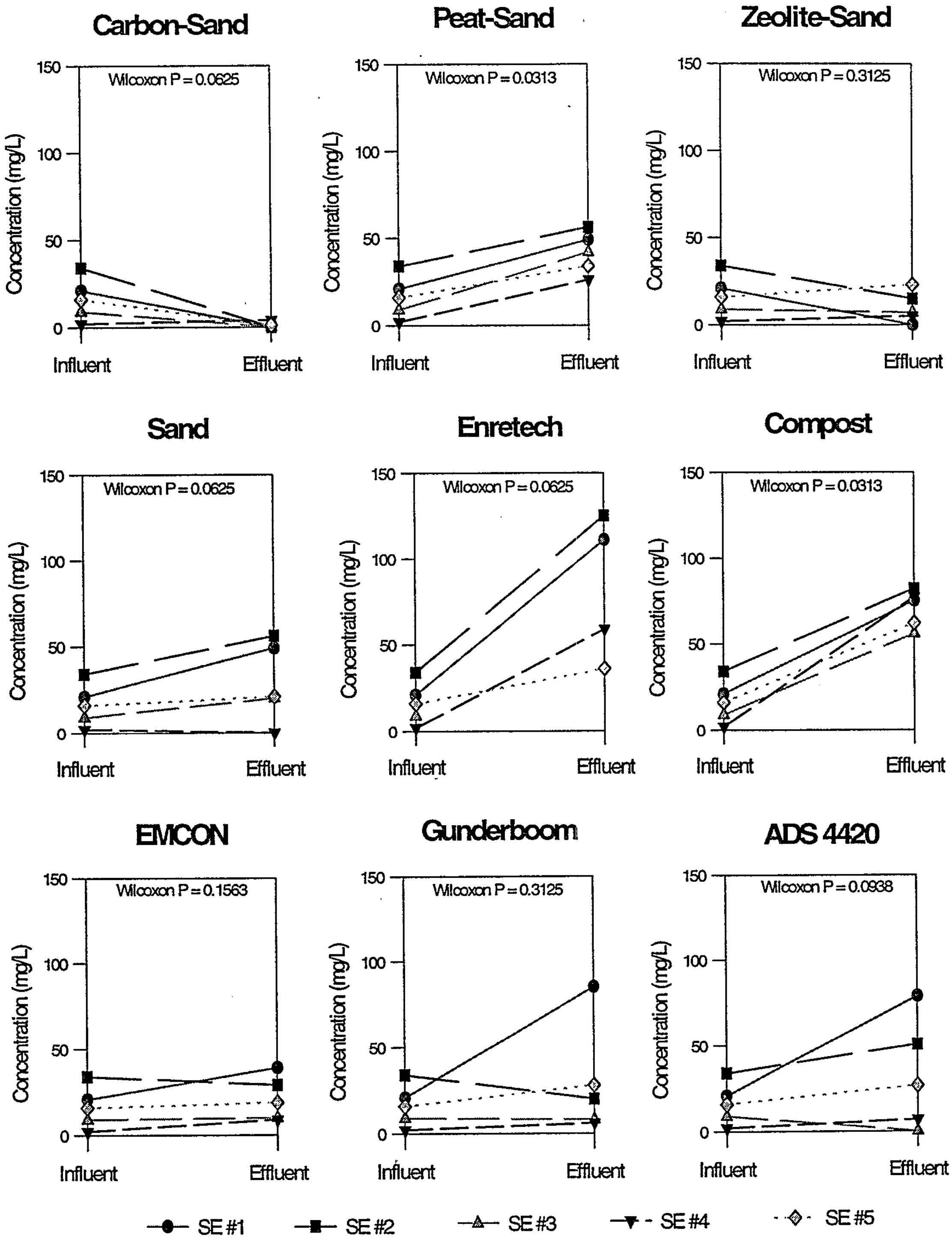
FILTRATION MEDIA EVALUATION: Unpretreated Influent
Summer 1994

COD (Continued)

SAMPLE GROUP NAME	Unfiltered Fraction (mg/L)			Filtered Fraction (mg/L)			Particulate Fraction (mg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Compost									
1.1 m	108	79	27	21	75	-257	87	4	95
2.2 m	54	150	-178	34	82	-141	20	68	-240
3.3 m	3	62	-1967	9	56	-522	0	6	N/A
4.4 m	0	100	N/A	2	77	-3750	0	23	N/A
5.5 m	52	67	-29	16	62	-288	36	5	86
EMCON Fabric									
1.1 m	108	33	69	21	39	-86	87	0	100
2.2 m	54	80	-48	34	29	15	20	51	-155
3.3 m	3	41	-1267	9	10	-11	0	31	N/A
4.4 m	0	13	N/A	2	9	-350	0	4	N/A
5.5 m	52	33	37	16	19	-19	36	14	61
Gunderboom Fabric									
1.1 m	108	30	72	21	85	-305	87	0	100
2.2 m	54	58	-7	34	20	41	20	38	-90
3.3 m	3	40	-1233	9	8	11	0	32	N/A
4.4 m	0	22	N/A	2	6	-200	0	16	N/A
5.5 m	52	33	37	16	28	-75	36	5	86
ADS 4420 Fabric									
1.1 m	108	98	9	21	79	-276	87	19	78
2.2 m	54	79	-46	34	51	-50	20	28	-40
3.3 m	3	45	-1400	9	0	100	0	45	N/A
4.4 m	0	18	N/A	2	7	-250	0	11	N/A
5.5 m	52	51	2	16	27	-69	36	24	33



CHEMICAL OXYGEN DEMAND: Unpretreated Influent Unfiltered Fraction



CHEMICAL OXYGEN DEMAND: Unpretreated Influent
Filtered Fraction

SEMI-VOLATILE ORGANICS

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Dichlorobenzene (µg/L)			n-Nitroso-di-n-propylamine (µg/L)			Nitrobenzene (µg/L)			2,4-Dimethylphenol (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m												
13.1 m	ND	ND	N/A	0.058	ND	100	0.051	ND	100	ND	ND	N/A
16.4 m	0.055	ND	100	ND	ND	N/A	ND	0.055	N/A	2.856	1.894	34
20.6 m	0.140	ND	100	ND	ND	N/A	ND	0.004	N/A	2.354	ND	100
25.0 m	0.135	0.172	-28	ND	0.091	N/A	0.033	0.010	69	ND	ND	N/A
Peat-Sand												
8.5 m												
13.1 m	ND	ND	N/A	0.058	0.106	-84	0.051	ND	100	ND	ND	N/A
16.4 m	0.055	ND	100	ND	0.011	N/A	ND	0.015	N/A	2.856	2.962	-4
20.6 m	0.140	0.047	67	ND	ND	N/A	ND	0.046	N/A	2.354	0.138	94
25.0 m	0.135	0.317	-136	ND	ND	N/A	0.033	0.018	45	ND	ND	N/A
Zeolite-Sand												
8.5 m												
13.1 m	ND	ND	N/A	0.058	ND	100	0.051	ND	100	ND	ND	N/A
16.4 m	0.055	ND	100	ND	ND	N/A	ND	ND	N/A	2.856	ND	100
20.6 m	0.140	0.043	69	ND	ND	N/A	ND	ND	N/A	2.354	1.257	47
25.0 m	0.135	ND	100	ND	ND	N/A	0.033	0.079	-141	ND	ND	N/A
Compost-Sand												
8.5 m												
13.1 m	ND	ND	N/A	0.058	0.108	-86	0.051	ND	100	ND	ND	N/A
16.4 m	0.055	0.459	-741	ND	0.030	N/A	ND	0.241	N/A	2.856	8.079	-183
20.6 m	0.140	ND	100	ND	ND	N/A	ND	ND	N/A	2.354	ND	100
25.0 m	0.135	ND	100	ND	0.029	N/A	0.033	0.006	81	ND	4.229	N/A
Enretech-Sand												
8.5 m		ND	N/A		ND	N/A		ND	N/A		ND	N/A
13.1 m	ND	ND	N/A	0.058	0.015	75	0.051	ND	100	ND	ND	N/A
16.4 m	0.055	0.103	-89	ND	0.040	N/A	ND	0.044	N/A	2.856	2.285	20
20.6 m	0.140	0.143	-2	ND	ND	N/A	ND	0.046	N/A	2.354	0.241	90
25.0 m	0.135	ND	100	ND	0.087	N/A	0.033	0.037	-14	ND	ND	N/A

SEMI-VOLATILE ORGANICS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent

Fall 1995

SAMPLE GROUP NAME	Dichlorobenzene (µg/L)			n-Nitroso-di-n-propylamine (µg/L)			Nitrobenzene (µg/L)			2,4-Dimethylphenol (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m		ND	N/A		0.000	N/A		ND	N/A		ND	N/A
13.1 m	ND	ND	N/A	0.058	0.073	-25	0.051	ND	100	ND	ND	N/A
16.4 m	0.055	0.099	-81	ND	0.023	N/A	ND	0.033	N/A	2.856	3.770	-32
20.6 m	0.140	ND	100	ND	ND	N/A	ND	ND	N/A	2.354	0.536	77
25.0 m	0.135	0.039	71	ND	ND	N/A	0.033	ND	100	ND	ND	N/A
Sand												
8.5 m		ND	N/A		0.114	N/A		0.044	N/A		0.074	N/A
13.1 m	ND	ND	N/A	0.058	ND	100	0.051	ND	100	ND	1.978	N/A
16.4 m	0.055	0.006	90	ND	ND	N/A	ND	0.043	N/A	2.856	5.730	-101
20.6 m	0.140	ND	100	ND	ND	N/A	ND	ND	N/A	2.354	ND	100
25.0 m	0.135	0.062	54	ND	ND	N/A	0.033	0.009	74	ND	ND	N/A
Gunderboom Fabric												
8.5 m		ND	N/A		0.104	N/A		0.034	N/A		ND	N/A
13.1 m	ND	ND	N/A	0.058	ND	100	0.051	0.006	88	ND	0.610	N/A
16.4 m	0.055	ND	100	ND	0.018	N/A	ND	0.012	N/A	2.856	3.855	-35
20.6 m	0.140	ND	100	ND	ND	N/A	ND	ND	N/A	2.354	1.515	36
25.0 m	0.135	ND	100	ND	ND	N/A	0.033	0.015	54	ND	ND	N/A
EMCON Fabric												
8.5 m		ND	N/A		0.052	N/A		ND	N/A		ND	N/A
13.1 m	ND	0.022	N/A	0.058	ND	100	0.051	0.019	62	ND	2.717	N/A
16.4 m	0.055	ND	100	ND	ND	N/A	ND	0.017	N/A	2.856	1.769	38
20.6 m	0.140	0.101	28	ND	ND	N/A	ND	ND	N/A	2.354	9.028	-283
25.0 m	0.135	0.175	-30	ND	ND	N/A	0.033	0.046	-42	ND	ND	N/A

SEMI-VOLATILE ORGANICS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Naphthalene (µg/L)			Dinitrotoluene (µg/L)			Acenaphthene (µg/L)			2,4-Dinitrophenol (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m												
13.1 m	ND	ND	N/A	ND	0.019	N/A	ND	ND	N/A	ND	ND	N/A
16.4 m	ND	0.015	N/A	0.081	ND	100	ND	ND	N/A	0.454	0.330	27
20.6 m	ND	0.067	N/A	ND	0.067	N/A	ND	ND	N/A	0.839	0.832	1
25.0 m	ND	ND	N/A	ND	0.381	N/A	0.015	ND	100	0.484	ND	100
Peat-Sand												
13.1 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A
16.4 m	ND	ND	N/A	0.081	0.111	-38	ND	ND	N/A	0.454	0.429	6
20.6 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.839	0.819	2
25.0 m	ND	ND	N/A	ND	ND	N/A	0.015	ND	100	0.484	ND	100
Zeolite-Sand												
8.5 m												
13.1 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A
16.4 m	ND	ND	N/A	0.081	ND	100	ND	ND	N/A	0.454	0.188	59
20.6 m	ND	0.060	N/A	ND	ND	N/A	ND	ND	N/A	0.839	1.071	-28
25.0 m	ND	ND	N/A	ND	0.086	N/A	0.015	ND	100	0.484	0.264	45
Compost-Sand												
8.5 m												
13.1 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A
16.4 m	ND	0.068	N/A	0.081	ND	100	ND	ND	N/A	0.454	0.889	-96
20.6 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.839	0.628	25
25.0 m	ND	ND	N/A	ND	ND	N/A	0.015	ND	100	0.484	ND	100
Enretech-Sand												
8.5 m		ND	N/A		ND	N/A		ND	N/A		0.148	N/A
13.1 m	ND	ND	N/A	ND	0.110	N/A	ND	ND	N/A	ND	ND	N/A
16.4 m	ND	0.005	N/A	0.081	ND	100	ND	ND	N/A	0.454	0.364	20
20.6 m	ND	0.077	N/A	ND	ND	N/A	ND	ND	N/A	0.839	0.533	36
25.0 m	ND	0.043	N/A	ND	ND	N/A	0.015	ND	100	0.484	0.315	35

FILTRATION MEDIA EVALUATION: PreSettled Influent

Fall 1995

SEMI-VOLATILE ORGANICS (Continued)

SAMPLE GROUP NAME	Naphthalene (μg/L)			Dinitrotoluene (μg/L)			Acenaphthene (μg/L)			2,4-Dinitrophenol (μg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m		ND	N/A		ND	N/A		ND	N/A		ND	N/A
13.1 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A
16.4 m	ND	0.055	N/A	0.081	ND	100	ND	ND	N/A	0.454	0.509	-12
20.6 m	ND	0.053	N/A	ND	ND	N/A	ND	0.061	N/A	0.839	1.273	-52
25.0 m	ND	ND	N/A	ND	ND	N/A	0.015	ND	100	0.484	0.158	67
Sand												
8.5 m		ND	N/A		ND	N/A		ND	N/A		ND	N/A
13.1 m	ND	0.010	N/A	ND	ND	N/A	ND	ND	N/A	ND	0.290	N/A
16.4 m	ND	ND	N/A	0.081	0.064	21	ND	ND	N/A	0.454	0.459	-1
20.6 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.839	0.235	72
25.0 m	ND	0.082	N/A	ND	0.362	N/A	0.015	ND	100	0.484	0.182	62
Gunderboom Fabric												
8.5 m		ND	N/A		ND	N/A		0.096	N/A		ND	N/A
13.1 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	ND	0.166	N/A
16.4 m	ND	0.002	N/A	0.081	ND	100	ND	ND	N/A	0.454	0.278	39
20.6 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.839	0.027	97
25.0 m	ND	0.039	N/A	ND	ND	N/A	0.015	ND	100	0.484	ND	100
EMCON Fabric												
8.5 m		ND	N/A		ND	N/A		ND	N/A		ND	N/A
13.1 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	ND	0.593	N/A
16.4 m	ND	ND	N/A	0.081	ND	100	ND	ND	N/A	0.454	0.630	-39
20.6 m	ND	0.022	N/A	ND	ND	N/A	ND	ND	N/A	0.839	1.048	-25
25.0 m	ND	0.009	N/A	ND	ND	N/A	0.015	ND	100	0.484	0.883	-83

SEMI-VOLATILE ORGANICS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Diethylphthalate (µg/L)			Fluorene (µg/L)			2-Methyl-4,6-dinitrophenol (µg/L)			n-Nitrosodiphenylamine (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m												
13.1 m	0.070	0.088	-26	ND	ND	N/A	ND	ND	N/A	ND	0.202	N/A
16.4 m	ND	ND	N/A	0.022	0.041	-90	0.328	ND	100	0.003	ND	100
20.6 m	ND	ND	N/A	0.081	0.254	-215	0.017	ND	100	ND	ND	N/A
25.0 m	ND	ND	N/A	0.021	ND	100	ND	0.205	N/A	ND	ND	N/A
Peat-Sand												
8.5 m												
13.1 m	0.070	0.063	10	ND	ND	N/A	ND	ND	N/A	ND	0.206	N/A
16.4 m	ND	0.028	N/A	0.022	0.040	-84	0.328	ND	100	0.003	0.016	-423
20.6 m	ND	0.070	N/A	0.081	ND	100	0.017	ND	100	ND	ND	N/A
25.0 m	ND	ND	N/A	0.021	0.195	-852	ND	ND	N/A	ND	ND	N/A
Zeolite-Sand												
8.5 m												
13.1 m	0.070	0.063	10	ND	ND	N/A	ND	ND	N/A	ND	0.203	N/A
16.4 m	ND	0.029	N/A	0.022	0.005	78	0.328	ND	100	0.003	ND	100
20.6 m	ND	0.109	N/A	0.081	0.038	53	0.017	ND	100	ND	0.228	N/A
25.0 m	ND	0.079	N/A	0.021	0.047	-129	ND	0.183	N/A	ND	0.110	N/A
Compost-Sand												
8.5 m												
13.1 m	0.070	0.069	1	ND	ND	N/A	ND	ND	N/A	ND	0.014	N/A
16.4 m	ND	ND	N/A	0.022	0.205	-848	0.328	0.640	-95	0.003	0.471	-15583
20.6 m	ND	0.017	N/A	0.081	ND	100	0.017	ND	100	ND	ND	N/A
25.0 m	ND	ND	N/A	0.021	0.113	-450	ND	ND	N/A	ND	0.156	N/A
Enretech-Sand												
8.5 m		0.064	N/A		ND	N/A		ND	N/A		0.263	N/A
13.1 m	0.070	0.048	32	ND	ND	N/A	ND	0.079	N/A	ND	0.007	N/A
16.4 m	ND	ND	N/A	0.022	0.013	41	0.328	ND	100	0.003	0.072	-2287
20.6 m	ND	ND	N/A	0.081	0.082	-2	0.017	0.035	-109	ND	0.091	N/A
25.0 m	ND	0.044	N/A	0.021	ND	100	ND	ND	N/A	ND	0.133	N/A

SEMI-VOLATILE ORGANICS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Diethylphthalate (µg/L)			Fluorene (µg/L)			2-Methyl-4,6-dinitrophenol (µg/L)			n-Nitrosodiphenylamine (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m		0.038	N/A		ND	N/A		ND	N/A		ND	N/A
13.1 m	0.070	0.061	12	ND	ND	N/A	ND	ND	N/A	ND	0.166	N/A
16.4 m	ND	ND	N/A	0.022	0.051	-134	0.328	0.104	68	0.003	0.078	-2497
20.6 m	ND	0.056	N/A	0.081	ND	100	0.017	ND	100	ND	ND	N/A
25.0 m	ND	0.060	N/A	0.021	0.081	-296	ND	ND	N/A	ND	0.092	N/A
Sand												
8.5 m		0.049	N/A		ND	N/A		0.140	N/A		0.154	N/A
13.1 m	0.070	0.035	49	ND	0.068	N/A	ND	ND	N/A	ND	0.012	N/A
16.4 m	ND	ND	N/A	0.022	ND	100	0.328	0.056	83	0.003	0.017	-453
20.6 m	ND	0.080	N/A	0.081	ND	100	0.017	ND	100	ND	ND	N/A
25.0 m	ND	ND	N/A	0.021	ND	100	ND	ND	N/A	ND	0.211	N/A
Gunderboom Fabric												
8.5 m		0.136	N/A		ND	N/A		ND	N/A		0.263	N/A
13.1 m	0.070	ND	100	ND	0.026	N/A	ND	ND	N/A	ND	0.059	N/A
16.4 m	ND	ND	N/A	0.022	0.034	-55	0.328	0.123	63	0.003	ND	100
20.6 m	ND	0.064	N/A	0.081	0.008	91	0.017	ND	100	ND	ND	N/A
25.0 m	ND	0.070	N/A	0.021	ND	100	ND	ND	N/A	ND	0.196	N/A
EMCON Fabric												
8.5 m		0.073	N/A		ND	N/A		ND	N/A		0.202	N/A
13.1 m	0.070	ND	100	ND	0.024	N/A	ND	0.035	N/A	ND	0.070	N/A
16.4 m	ND	ND	N/A	0.022	0.002	90	0.328	ND	100	0.003	ND	100
20.6 m	ND	ND	N/A	0.081	0.058	28	0.017	ND	100	ND	ND	N/A
25.0 m	ND	ND	N/A	0.021	0.039	-92	ND	0.133	N/A	ND	0.097	N/A

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SEMI-VOLATILE ORGANICS (Continued)

SAMPLE GROUP NAME	2,4,6-Tribromophenol (µg/L)			4-Bromophenylphenylether (µg/L)			Pentachlorophenol (µg/L)			Carbazole (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m												
13.1 m	ND	ND	N/A	ND	ND	N/A	0.002	ND	100	0.026	0.037	-43
16.4 m	ND	ND	N/A	0.130	0.227	-74	0.004	ND	100	ND	ND	N/A
20.6 m	0.240	ND	100	0.000	ND	100	0.718	1.276	-78	0.191	ND	100
25.0 m	ND	1.557	N/A	ND	0.005	N/A	0.410	ND	100	ND	ND	N/A
Peat-Sand												
8.5 m												
13.1 m	ND	ND	N/A	ND	ND	N/A	0.002	0.132	-7228	0.026	0.075	-192
16.4 m	ND	ND	N/A	0.130	0.092	30	0.004	ND	100	ND	0.022	N/A
20,6 m	0.240	ND	100	0.000	ND	100	0.718	0.370	48	0.191	ND	100
25.0 m	ND	ND	N/A	ND	0.019	N/A	0.410	ND	100	ND	0.162	N/A
Zeolite-Sand												
8.5 m												
13.1 m	ND	ND	N/A	ND	ND	N/A	0.002	ND	100	0.026	0.076	-196
16.4 m	ND	0.420	N/A	0.130	ND	100	0.004	ND	100	ND	ND	N/A
20.6 m	0.240	ND	100	0.000	ND	100	0.718	ND	100	0.191	ND	100
25.0 m	ND	ND	N/A	ND	0.005	N/A	0.410	0.345	16	ND	0.032	N/A
Compost-Sand												
8.5 m												
13.1 m	ND	ND	N/A	ND	ND	N/A	0.002	0.170	-9344	0.026	0.051	-100
16.4 m	ND	ND	N/A	0.130	0.653	-401	0.004	0.230	-5498	ND	ND	N/A
20.6 m	0.240	ND	100	0.000	ND	100	0.718	0.221	69	0.191	ND	100
25.0 m	ND	ND	N/A	ND	0.003	N/A	0.410	ND	100	ND	ND	N/A
Enretech-Sand												
8.5 m		ND	N/A		0.004	N/A		ND	N/A		0.072	N/A
13.1 m	ND	0.778	N/A	ND	ND	N/A	0.002	ND	100	0.026	0.089	-245
16.4 m	ND	ND	N/A	0.130	ND	100	0.004	ND	100	ND	ND	N/A
20.6 m	0.240	0.324	-35	0.000	0.012	-2900	0.718	0.385	46	0.191	ND	100
25.0 m	ND	0.765	N/A	ND	0.008	N/A	0.410	ND	100	ND	ND	N/A

SEMI-VOLATILE ORGANICS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	2,4,6-Tribromophenol (µg/L)			4-Bromophenylphenylether (µg/L)			Pentachlorophenol (µg/L)			Carbazole (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m		ND	N/A		ND	N/A		ND	N/A		0.055	N/A
13.1 m	ND	ND	N/A	ND	ND	N/A	0.002	ND	100	0.026	0.063	-145
16.4 m	ND	ND	N/A	0.130	0.205	-57	0.004	ND	100	ND	0.014	N/A
20.6 m	0.240	ND	100	0.000	0.000	75	0.718	0.237	67	0.191	ND	100
25.0 m	ND	ND	N/A	ND	0.005	N/A	0.410	ND	100	ND	ND	N/A
Sand												
8.5 m		ND	N/A		ND	N/A		0.189	N/A		0.064	N/A
13.1 m	ND	ND	N/A	ND	0.002	N/A	0.002	ND	100	0.026	ND	100
16.4 m	ND	ND	N/A	0.130	0.221	N/A	0.004	ND	100	ND	ND	N/A
20.6 m	0.240	ND	100	0.000	ND	N/A	0.718	ND	100	0.191	ND	100
25.0 m	ND	1.395	N/A	ND	0.004	N/A	0.410	ND	100	ND	0.061	N/A
Gunderboom Fabric												
8.5 m		ND	N/A		ND	N/A		ND	N/A		0.064	N/A
13.1 m	ND	ND	N/A	ND	0.008	N/A	0.002	ND	100	0.026	ND	100
16.4 m	ND	0.064	N/A	0.130	0.164	-26	0.004	0.213	-5095	ND	ND	N/A
20.6 m	0.240	0.065	73	0.000	0.004	-850	0.718	0.309	57	0.191	ND	100
25.0 m	ND	ND	N/A	ND	ND	N/A	0.410	ND	100	ND	ND	N/A
EMCON Fabric												
8.5 m		ND	N/A		ND	N/A		ND	N/A		0.033	N/A
13.1 m	ND	ND	N/A	ND	0.005	N/A	0.002	0.138	-7561	0.026	0.001	97
16.4 m	ND	ND	N/A	0.130	ND	100	0.004	0.960	-23322	ND	ND	N/A
20.6 m	0.240	ND	100	0.000	ND	100	0.718	0.547	24	0.191	ND	100
25.0 m	ND	ND	N/A	ND	0.007	N/A	0.410	ND	100	ND	ND	N/A

SEMI-VOLATILE ORGANICS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Di-n-butylphthalate (µg/L)			Fluoranthene (µg/L)			Pyrene (µg/L)			4-Terphenyl (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m												
13.1 m	0.605	0.863	-43	0.070	0.054	23	0.035	0.032	9	0.060	ND	100
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.090	ND	100
20.6 m	0.237	0.002	99	ND	ND	N/A	ND	ND	N/A	0.186	0.181	3
25.0 m	0.234	ND	100	ND	ND	N/A	ND	ND	N/A	0.105	0.206	-96
Peat-Sand												
8.5 m												
13.1 m	0.605	0.465	23	0.070	0.002	97	0.035	ND	100	0.060	ND	100
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.090	0.037	59
20.6 m	0.237	0.060	75	ND	ND	N/A	ND	ND	N/A	0.186	0.323	-73
25.0 m	0.234	ND	100	ND	ND	N/A	ND	ND	N/A	0.105	0.099	6
Zeolite-Sand												
8.5 m												
13.1 m	0.605	0.744	-23	0.070	0.059	16	0.035	0.449	-1179	0.060	ND	100
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.090	ND	100
20.6 m	0.237	0.226	4	ND	ND	N/A	ND	ND	N/A	0.186	0.480	-158
25.0 m	0.234	ND	100	ND	ND	N/A	ND	ND	N/A	0.105	ND	100
Compost-Sand												
8.5 m												
13.1 m	0.605	0.681	-13	0.070	0.054	23	0.035	0.017	53	0.060	ND	100
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.090	0.221	-146
20.6 m	0.237	0.260	-10	ND	ND	N/A	ND	ND	N/A	0.186	0.252	-36
25.0 m	0.234	ND	100	ND	ND	N/A	ND	ND	N/A	0.105	ND	100
Enretech-Sand												
8.5 m		0.164	N/A		0.055	N/A		0.046	N/A		ND	N/A
13.1 m	0.605	0.673	-11	0.070	0.051	28	0.035	ND	100	0.060	ND	100
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.090	0.051	43
20.6 m	0.237	0.252	-6	ND	0.002	N/A	ND	ND	N/A	0.186	0.343	-85
25.0 m	0.234	ND	100	ND	ND	N/A	ND	ND	N/A	0.105	ND	100

SEMI-VOLATILE ORGANICS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Di-n-butylphthalate (µg/L)			Fluoranthene (µg/L)			Pyrene (µg/L)			4-Terphenyl (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m		0.090	N/A		0.084	N/A		0.053	N/A		0.014	N/A
13.1 m	0.605	0.660	-9	0.070	0.055	21	0.035	ND	100	0.060	ND	100
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.090	0.168	-86
20.6 m	0.237	0.270	-14	ND	0.000	N/A	ND	ND	N/A	0.186	0.253	-36
25.0 m	0.234	0.075	68	ND	ND	N/A	ND	ND	N/A	0.105	ND	100
Sand												
8.5 m		0.064	N/A		0.062	N/A		ND	N/A		ND	N/A
13.1 m	0.605	0.004	99	0.070	ND	100	0.035	ND	100	0.060	ND	100
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.090	0.034	62
20.6 m	0.237	0.314	-33	ND	0.019	N/A	ND	ND	N/A	0.186	0.079	58
25.0 m	0.234	ND	100	ND	ND	N/A	ND	0.596	N/A	0.105	ND	100
Gunderboom Fabric												
8.5 m		0.238	N/A		0.155	N/A		0.138	N/A		ND	N/A
13.1 m	0.605	ND	100	0.070	ND	100	0.035	0.001	96	0.060	ND	100
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	0.090	0.011	88
20.6 m	0.237	0.172	27	ND	ND	N/A	ND	ND	N/A	0.186	0.285	-53
25.0 m	0.234	ND	100	ND	ND	N/A	ND	0.058	N/A	0.105	ND	100
EMCON Fabric												
8.5 m		0.715	N/A		0.057	N/A		0.050	N/A		ND	N/A
13.1 m	0.605	ND	100	0.070	ND	100	0.035	ND	100	0.060	0.013	78
16.4 m	ND	0.211	N/A	ND	0.001	N/A	ND	ND	N/A	0.090	0.229	-155
20.6 m	0.237	0.210	11	ND	0.002	N/A	ND	ND	N/A	0.186	0.286	-54
25.0 m	0.234	ND	100	ND	ND	N/A	ND	0.064	N/A	0.105	ND	100

SEMI-VOLATILE ORGANICS (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Benzylbutylphthalate (µg/L)			Benzo(a)anthracene (µg/L)			Chrysene (µg/L)			Bis(2-ethylhexyl)phthalate (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m												
13.1 m	0.098	0.168	-71	ND	ND	N/A	ND	ND	N/A	2.500	0.367	85
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	1.340	0.101	93
20.6 m	ND	ND	N/A	0.032	0.070	-120	0.002	0.043	-2429	0.740	0.070	91
25.0 m	ND	ND	N/A	0.055	ND	100	0.028	ND	100	ND	ND	N/A
Peat-Sand												
8.5 m												
13.1 m	0.098	0.078	21	ND	ND	N/A	ND	ND	N/A	2.500	0.892	64
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	1.340	0.994	26
20.6 m	ND	ND	N/A	0.032	0.002	93	0.002	ND	100	0.740	0.541	27
25.0 m	ND	ND	N/A	0.055	ND	100	0.028	ND	100	ND	ND	N/A
Zeolite-Sand												
8.5 m												
13.1 m	0.098	0.146	-49	ND	ND	N/A	ND	ND	N/A	2.500	0.367	85
16.4 m	ND	ND	N/A	ND	0.011	N/A	ND	ND	N/A	1.340	0.437	67
20.6 m	ND	ND	N/A	0.032	0.038	-21	0.002	0.009	-429	0.740	0.051	93
25.0 m	ND	ND	N/A	0.055	ND	100	0.028	ND	100	ND	ND	N/A
Compost-Sand												
8.5 m												
13.1 m	0.098	0.103	-5	ND	ND	N/A	ND	ND	N/A	2.500	0.464	81
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	1.340	0.526	61
20.6 m	ND	ND	N/A	0.032	0.041	-28	0.002	0.012	-582	0.740	1.174	-59
25.0 m	ND	ND	N/A	0.055	ND	100	0.028	ND	100	ND	ND	N/A
Enretech-Sand												
8.5 m		0.087	N/A		ND	N/A		ND	N/A		0.433	N/A
13.1 m	0.098	0.143	-45	ND	ND	N/A	ND	ND	N/A	2.500	0.467	81
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	1.340	0.575	57
20.6 m	ND	ND	N/A	0.032	0.062	-97	0.002	0.035	-1965	0.740	2.165	-192
25.0 m	ND	ND	N/A	0.055	ND	100	0.028	ND	100	ND	ND	N/A

FILTRATION MEDIA EVALUATION: PreSettled Influent

Fall 1995

SEMI-VOLATILE ORGANICS (Continued)

SAMPLE GROUP NAME	Benzylbutylphthalate (µg/L)			Benzo(a)anthracene (µg/L)			Chrysene (µg/L)			Bis(2-ethylhexyl)phthalate (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m		0.047	N/A		ND	N/A		ND	N/A		0.343	N/A
13.1 m	0.098	0.097	1	ND	ND	N/A	ND	ND	N/A	2.500	0.236	91
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	1.340	0.152	89
20.6 m	ND	ND	N/A	0.032	ND	100	0.002	ND	100	0.740	1.504	-103
25.0 m	ND	0.005	N/A	0.055	ND	100	0.028	ND	100	ND	ND	N/A
Sand												
8.5 m		0.014	N/A		ND	N/A		ND	N/A		0.284	N/A
13.1 m	0.098	ND	100	ND	ND	N/A	ND	ND	N/A	2.500	0.075	97
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	1.340	0.220	84
20.6 m	ND	ND	N/A	0.032	0.039	-23	0.002	0.010	-476	0.740	ND	100
25.0 m	ND	ND	N/A	0.055	ND	100	0.028	ND	100	ND	ND	N/A
Gunderboom Fabric												
8.5 m		0.109	N/A		ND	N/A		ND	N/A		11.822	N/A
13.1 m	0.098	0.004	96	ND	ND	N/A	ND	ND	N/A	2.500	1.581	37
16.4 m	ND	ND	N/A	ND	ND	N/A	ND	ND	N/A	1.340	1.199	11
20.6 m	ND	ND	N/A	0.032	0.076	-140	0.002	0.050	-2829	0.740	0.064	91
25.0 m	ND	ND	N/A	0.055	ND	100	0.028	ND	100	ND	2.316	N/A
EMCON Fabric												
8.5 m		0.190	N/A		ND	N/A		ND	N/A		3.137	N/A
13.1 m	0.098	ND	100	ND	ND	N/A	ND	ND	N/A	2.500	2.236	11
16.4 m	ND	ND	N/A	ND	0.066	N/A	ND	0.039	N/A	1.340	4.534	-238
20.6 m	ND	ND	N/A	0.032	0.054	-71	0.002	0.026	-1441	0.740	ND	100
25.0 m	ND	ND	N/A	0.055	ND	100	0.028	ND	100	ND	1.709	N/A

SEMI-VOLATILE ORGANICS (Continued)

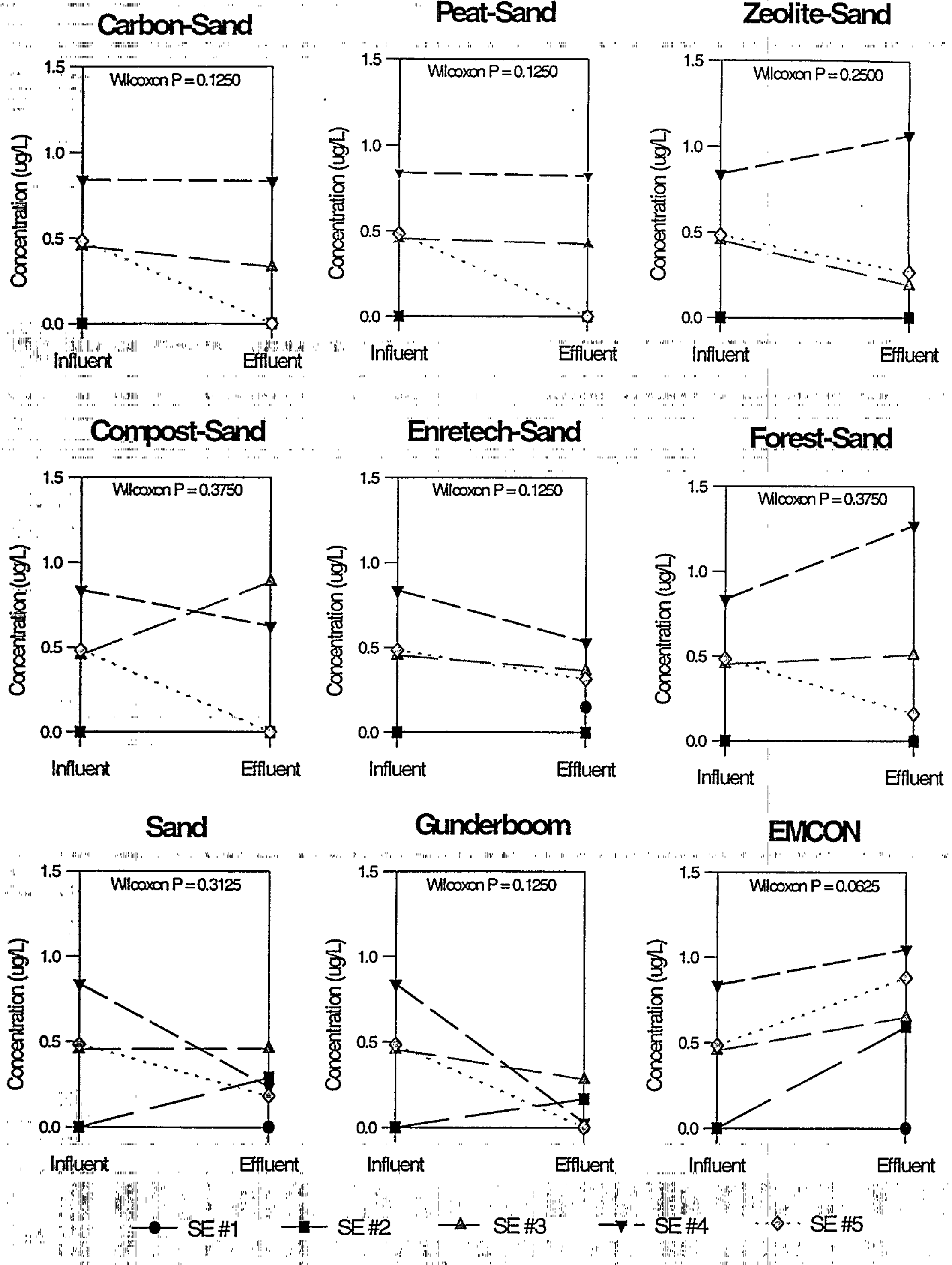
FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Benzo(b)fluoranthene/...(k)... (µg/L)			Benzo(a)pyrene (µg/L)			Indeno(1,2,3-c,d)pyrene (µg/L)			Dibenz(a,h)anthracene (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m												
13.1 m	0.037	0.052	-40	0.026	0.022	15	0.021	ND	100	ND	ND	N/A
16.4 m	0.024	0.050	-107	ND	ND	N/A	0.072	0.005	94	0.003	0.030	-850
20.6 m	0.102	0.088	14	0.151	ND	100	0.000	ND	100	1.087	ND	100
25.0 m	0.021	0.027	-28	ND	ND	N/A	ND	ND	N/A	0.062	ND	100
Peat-Sand												
8.5 m												
13.1 m	0.037	0.076	-107	0.026	ND	100	0.021	0.012	43	ND	ND	N/A
16.4 m	0.024	0.034	-42	ND	0.005	N/A	0.072	ND	100	0.003	0.006	-91
20.6 m	0.102	0.065	36	0.151	ND	100	0.000	0.003	-2900	1.087	0.455	58
25.0 m	0.021	ND	100	ND	0.041	N/A	ND	ND	N/A	0.062	ND	100
Zeolite-Sand												
8.5 m												
13.1 m	0.037	0.058	-56	0.026	0.020	23	0.021	ND	100	ND	ND	N/A
16.4 m	0.024	0.041	-69	ND	0.019	N/A	0.072	ND	100	0.003	ND	100
20.6 m	0.102	ND	100	0.151	0.132	13	0.000	ND	100	1.087	ND	100
25.0 m	0.021	ND	100	ND	0.018	N/A	ND	ND	N/A	0.062	ND	100
Compost-Sand												
8.5 m												
13.1 m	0.037	0.075	-104	0.026	0.010	62	0.021	0.022	-2	ND	ND	N/A
16.4 m	0.024	0.100	-316	ND	ND	N/A	0.072	0.127	-77	0.003	ND	100
20.6 m	0.102	ND	100	0.131	ND	100	0.000	ND	100	1.087	ND	100
25.0 m	0.021	ND	100	ND	0.019	N/A	ND	ND	N/A	0.062	ND	100
Enretech-Sand												
8.5 m		0.059	N/A		0.002	N/A		0.025	N/A		ND	N/A
13.1 m	0.037	0.044	-19	0.026	0.013	51	0.021	ND	100	ND	ND	N/A
16.4 m	0.024	0.103	-328	ND	ND	N/A	0.072	0.020	72	0.003	ND	100
20.6 m	0.102	0.096	6	0.132	ND	100	0.000	0.002	-1400	1.087	0.589	46
25.0 m	0.021	0.082	-295	ND	ND	N/A	ND	ND	N/A	0.062	ND	100

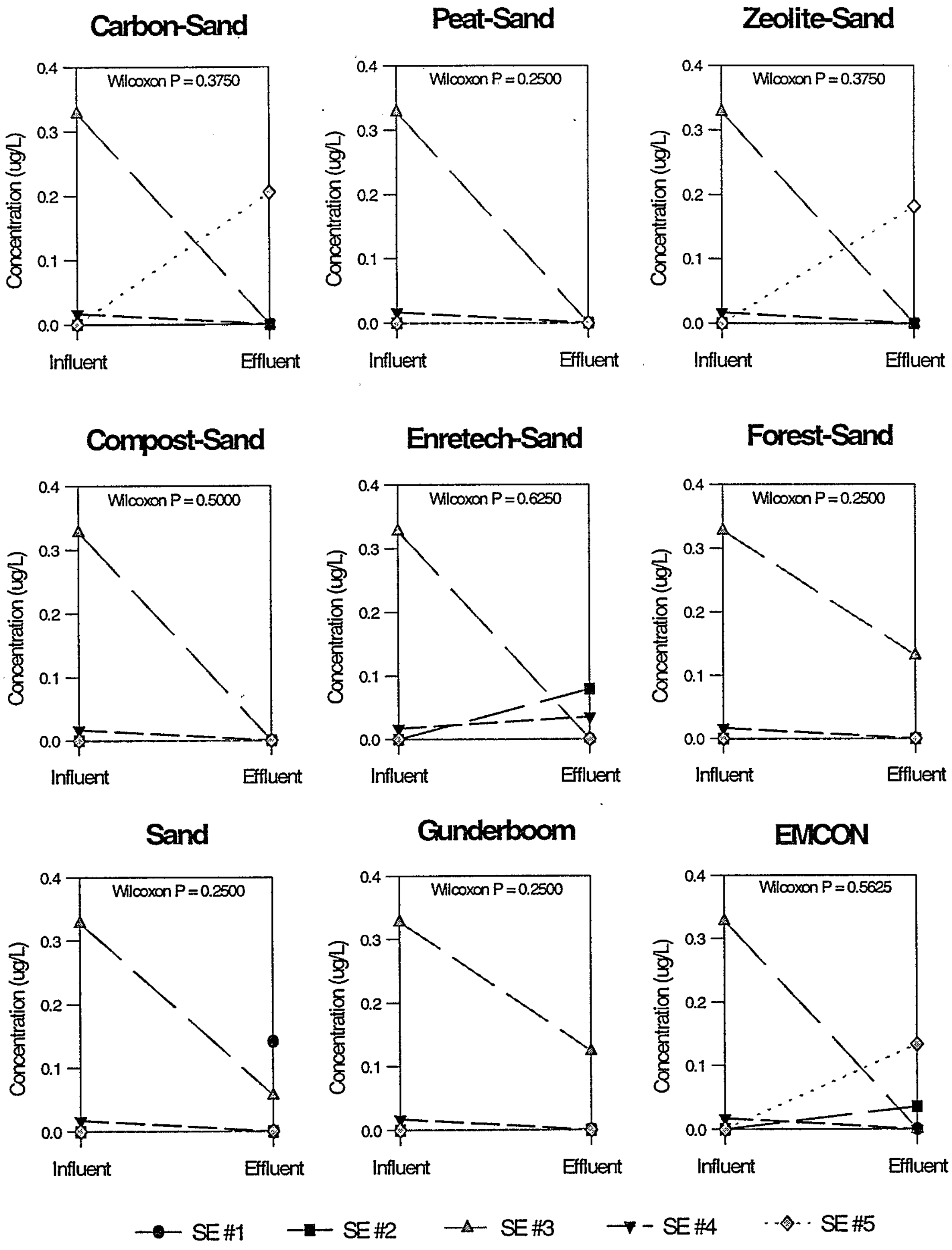
FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SEMI-VOLATILE ORGANICS (Continued)

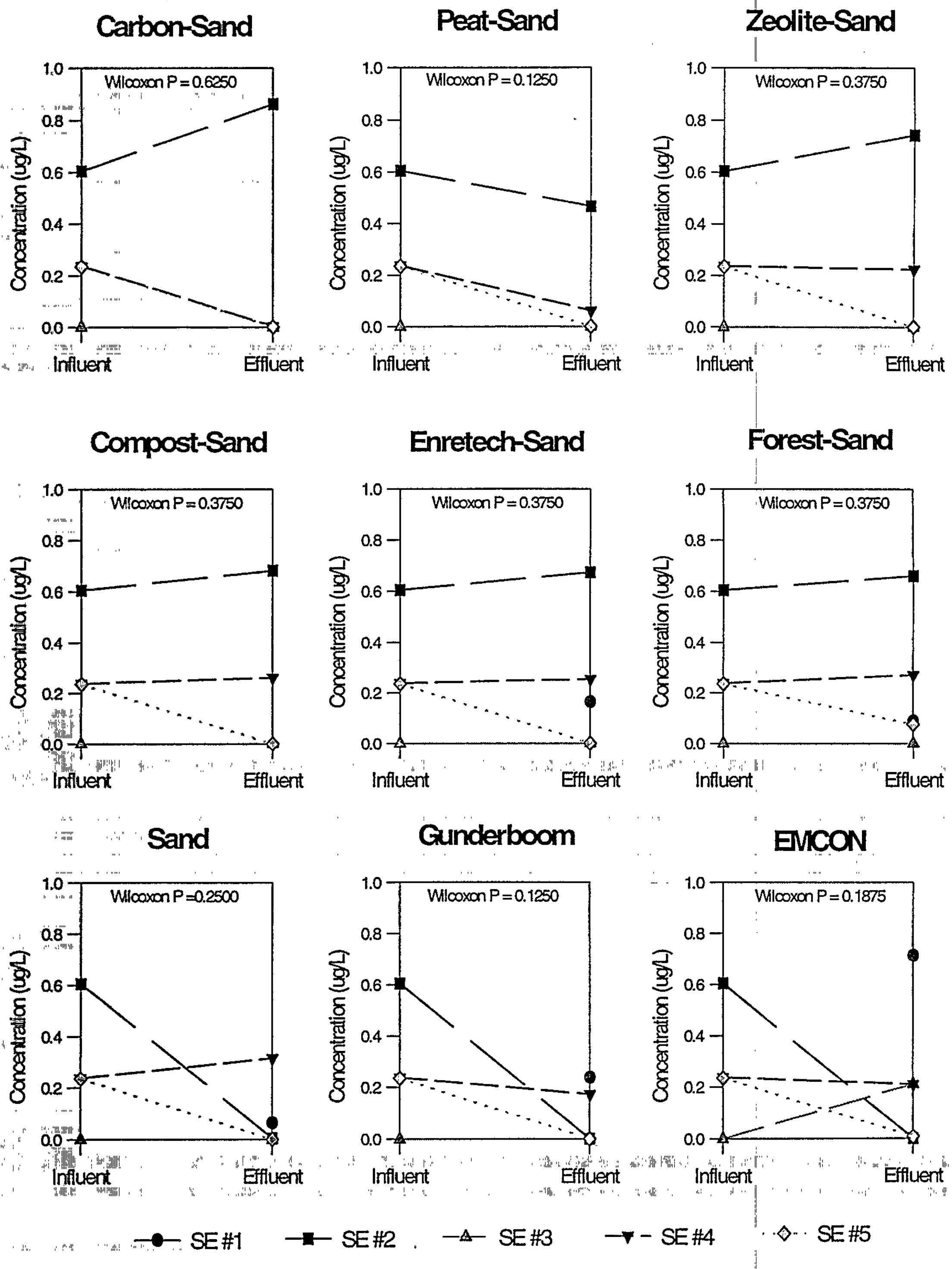
SAMPLE GROUP NAME	Benzo(b)fluoranthene/...(k)... (µg/L)			Benzo(a)pyrene (µg/L)			Indeno(1,2,3-c,d)pyrene (µg/L)			Dibenz(a,h)anthracene (µg/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m		0.063	N/A		0.018	N/A		ND	N/A		ND	N/A
13.1 m	0.037	0.048	-30	0.026	0.021	21	0.021	ND	100	ND	ND	N/A
16.4 m	0.024	ND	100	ND	ND	N/A	0.072	0.850	-1082	0.003	ND	100
20.6 m	0.102	ND	100	0.132	ND	100	0.000	ND	100	1.087	0.382	65
25.0 m	0.021	ND	100	ND	0.050	N/A	ND	ND	N/A	0.062	ND	100
Sand												
8.5 m		0.025	N/A		ND	N/A		ND	N/A		ND	N/A
13.1 m	0.037	0.053	-44	0.026	ND	100	0.021	ND	100	ND	0.030	N/A
16.4 m	0.024	0.069	-188	ND	0.000	N/A	0.072	0.079	-10	0.003	ND	100
20.6 m	0.102	ND	100	0.132	0.174	-32	0.000	ND	100	1.087	ND	100
25.0 m	0.021	ND	100	ND	0.038	N/A	ND	ND	N/A	0.062	ND	100
Gunderboom Fabric												
8.5 m		0.074	N/A		ND	N/A		0.051	N/A		ND	N/A
13.1 m	0.037	0.084	-126	0.026	ND	100	0.021	ND	100	ND	0.011	N/A
16.4 m	0.024	0.042	-77	ND	ND	N/A	0.072	ND	100	0.003	0.029	-809
20.6 m	0.102	0.054	47	0.132	0.189	-44	0.000	0.006	-6100	1.087	0.405	63
25.0 m	0.021	ND	100	ND	0.006	N/A	ND	ND	N/A	0.062	ND	100
EMCON Fabric												
8.5 m		0.030	N/A		0.023	N/A		ND	N/A		ND	N/A
13.1 m	0.037	0.058	-58	0.026	ND	100	0.021	ND	100	ND	0.051	N/A
16.4 m	0.024	ND	100	ND	ND	N/A	0.072	ND	100	0.003	0.419	-13000
20.6 m	0.102	ND	100	0.132	0.114	14	0.000	ND	100	1.087	ND	100
25.0 m	0.021	ND	100	ND	ND	N/A	ND	ND	N/A	0.062	ND	100



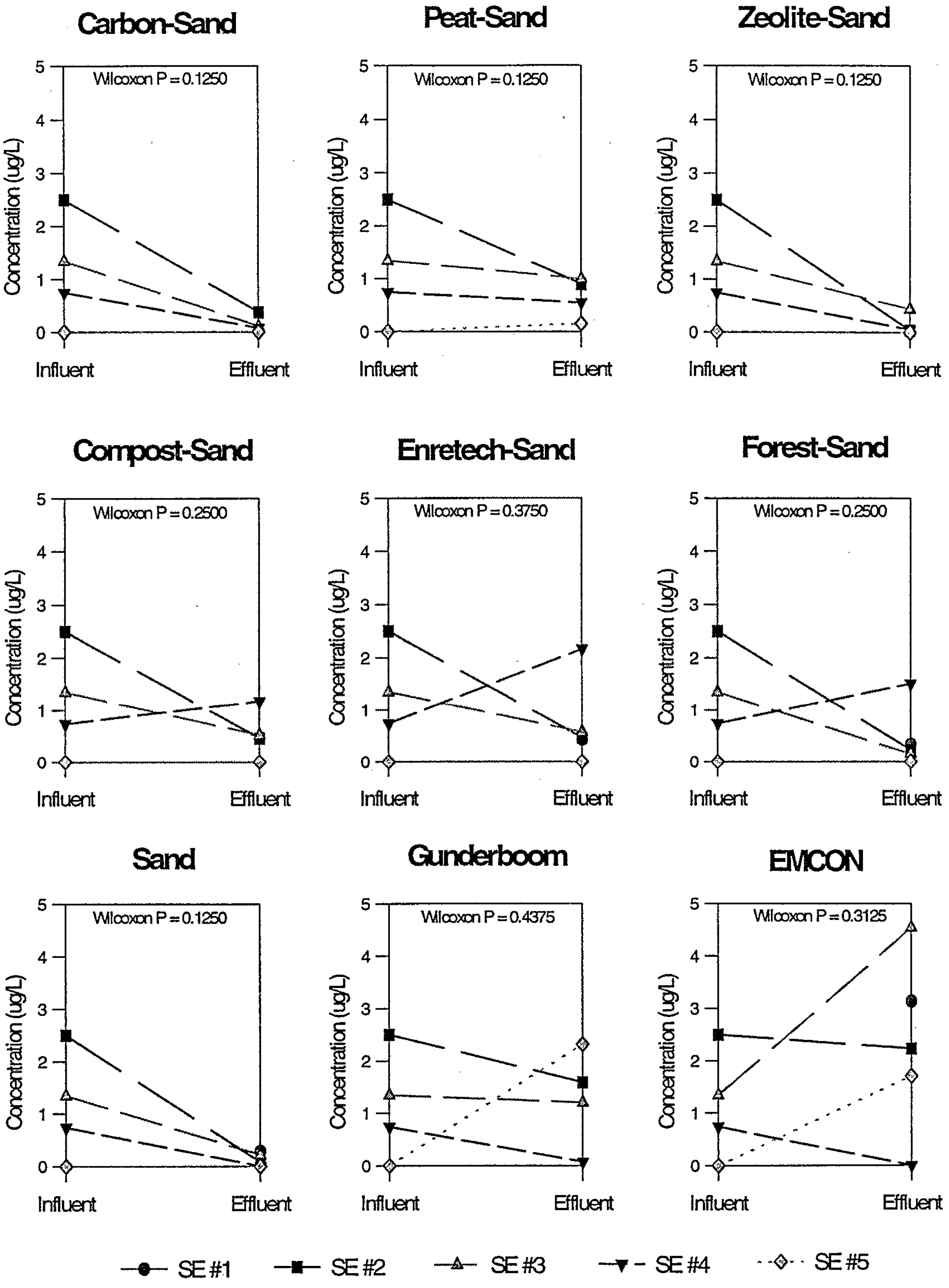
2,4-DINITROPHENOL: PreSettled Influent



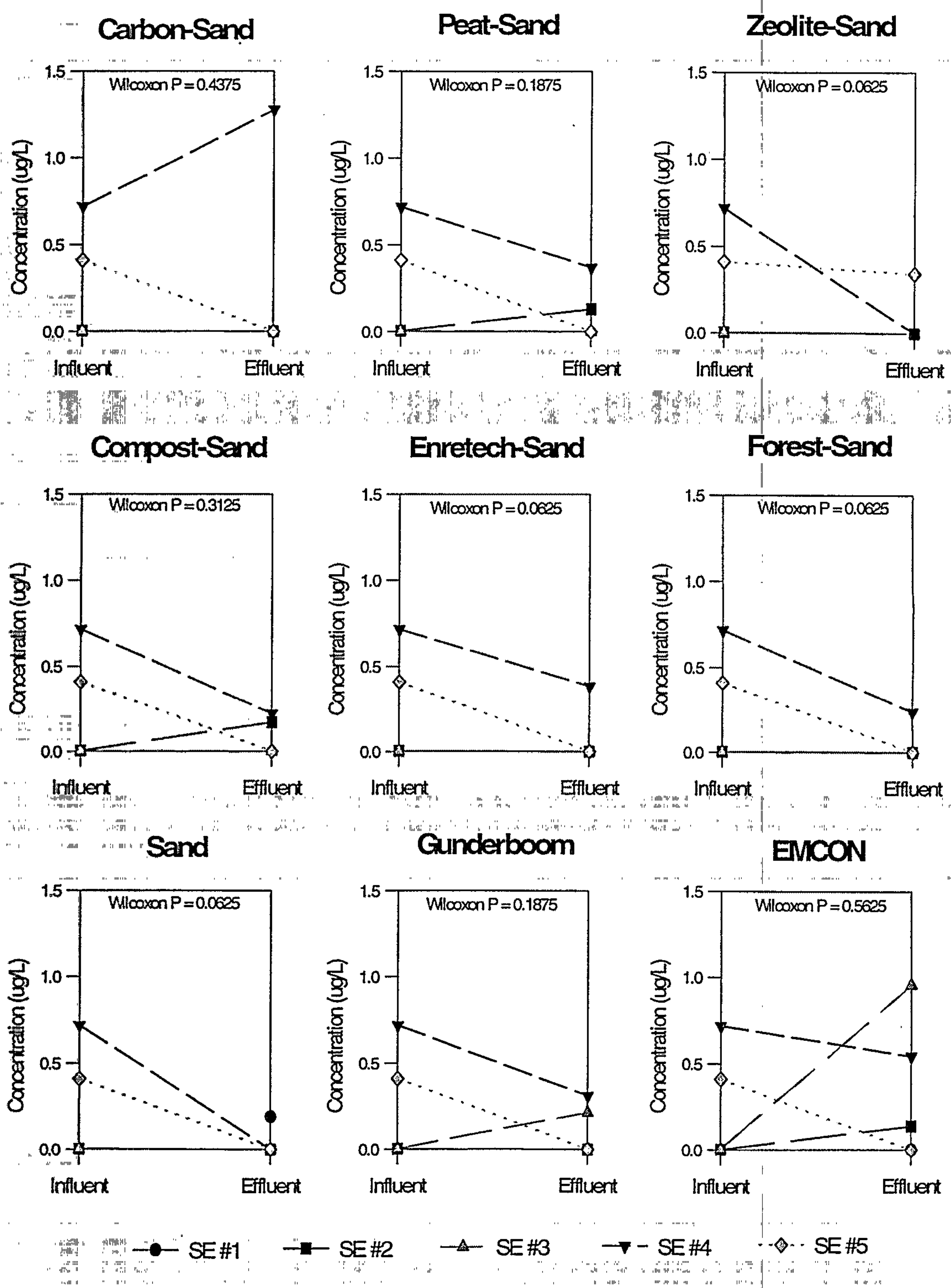
2-METHYL-4,6-DINITROPHENOL: PreSettled Influent



DI-N-BUTYLPHTHALATE: PreSettled Influent



BIS(2-ETHYLHEXYL)PHTHALATE: PreSettled Influent



PENTACHLOROPHENOL: PreSettled Influent

PESTICIDES

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Alpha-BHC (ng/L)			Gamma-BHC (ng/L)			Heptachlor (ng/L)			Aldrin (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	0.870	nd	100	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	1.338	nd	100	nd	nd	N/A
Peat-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	0.870	0.622	29	nd	3.772	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	1.338	nd	100	nd	nd	N/A
Zeolite-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	0.870	nd	100	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	2.227	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	1.338	nd	100	nd	nd	N/A
Compost-Sand												
8.5 m	nd		N/A	nd		N/A	0.870		100	nd		N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	10.034	N/A	nd	nd	N/A	1.338	2.386	-78	nd	4.229	N/A
Enretech-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	0.870	2.381	-174	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	1.383	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	1.338	nd	100	nd	nd	N/A

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

PESTICIDES (Continued)

SAMPLE GROUP NAME	Alpha-BHC (ng/L)			Gamma-BHC (ng/L)			Heptachlor (ng/L)			Aldrin (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	nd	nd	N/A	nd	566.303	N/A	0.870	nd	100	nd	7.427	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	4.422	N/A
16.4 m	nd	nd	N/A	nd	328.517	N/A	nd	nd	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	31.447	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	1.338	nd	100	nd	nd	N/A
Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	0.870	nd	100	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	17.006	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	1.338	nd	100	nd	nd	N/A
Gunderboom Fabric												
8.5 m	nd	nd	N/A	nd	nd	N/A	0.870	nd	100	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	27.124	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	1.338	nd	100	nd	nd	N/A
EMCON Fabric												
8.5 m	nd	nd	N/A	nd	nd	N/A	0.870	nd	100	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	22.114	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	17.598	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	1.338	nd	100	nd	nd	N/A

FILTRATION MEDIA EVALUATION: PreSettled Influent

Fall 1995

PESTICIDES (Continued)

SAMPLE GROUP NAME	Heptachlor Epoxide (ng/L)			Gamma-Chlordane (ng/L)			Endosulfan I (ng/L)			Alpha-Chlordane (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	3.876	nd	100	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	8.839	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Peat-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	3.876	nd	100	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	1.603	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Zeolite-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	3.876	4.286	-11	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	2.995	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Compost-Sand												
8.5 m	nd		N/A	nd		N/A	nd		N/A	nd		N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	3.876	7.082	-83	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	2.100	N/A	nd	1.719	N/A	nd	5.048	N/A	nd	nd	N/A
Enretech-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	nd	3.903	N/A	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	1.700	N/A	3.876	2.171	44	nd	1.568	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	nd	1.826	N/A	nd	nd	N/A

PESTICIDES (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Heptachlor Epoxide (ng/L)			Gamma-Chlordane (ng/L)			Endosulfan I (ng/L)			Alpha-Chlordane (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	nd	27.352	N/A	nd	2.536	N/A	nd	5.320	N/A	nd	7.249	N/A
13.1 m	nd	5.571	N/A	nd	4.309	N/A	3.876	nd	100	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	6.983	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	nd	2.945	N/A	nd	nd	N/A
Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	nd	4.202	N/A	nd	nd	N/A
13.1 m	nd	2.750	N/A	nd	nd	N/A	3.876	5.402	-39	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	4.659	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	nd	0.005	N/A	nd	nd	N/A
Gunderboom Fabric												
8.5 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	3.876	6.872	-77	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	1.464	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
EMCON Fabric												
8.5 m	nd	nd	N/A	nd	nd	N/A	nd	1.652	N/A	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	3.876	19.290	-398	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A

PESTICIDES (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Dieldrin (ng/L)			4,4'-DDE (ng/L)			Endrin (ng/L)			Endosulfan II (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	nd	1.068	N/A	nd	2.129	N/A	nd	nd	N/A	303.991	222.025	27
13.1 m	14.457	17.754	-23	nd	nd	N/A	5.522	nd	100	nd	nd	N/A
16.4 m	15.467	0.008	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	nd	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	1.998	0.641	68	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Peat-Sand												
8.5 m	nd	0.871	N/A	nd	nd	N/A	nd	nd	N/A	303.991	241.679	20
13.1 m	14.457	11.674	19	nd	nd	N/A	5.522	nd	100	nd	nd	N/A
16.4 m	15.467	nd	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	nd	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	1.998	0.956	52	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Zeolite-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	303.991	nd	100
13.1 m	14.457	16.593	-15	nd	nd	N/A	5.522	4.688	15	nd	nd	N/A
16.4 m	15.467	0.683	96	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	3.003	-147	nd	1.444	N/A	nd	nd	N/A	nd	7.368	N/A
25.0 m	1.998	1.556	22	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Compost-Sand												
8.5 m	nd		N/A	nd		N/A	nd		N/A	303.991		100
13.1 m	14.457	12.393	14	nd	nd	N/A	5.522	nd	100	nd	5.926	N/A
16.4 m	15.467	1.546	90	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	4.219	-247	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	1.998	4.353	-118	nd	nd	N/A	nd	2.045	N/A	nd	1.622	N/A
Enretech-Sand												
8.5 m	nd	3.139	N/A	nd	nd	N/A	nd	6.507	N/A	303.991	22.926	92
13.1 m	14.457	15.793	-9	nd	nd	N/A	5.522	nd	100	nd	nd	N/A
16.4 m	15.467	1.761	89	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	2.474	-104	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	1.998	2.181	-9	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A

PESTICIDES (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	Dieldrin (ng/L)			4,4'-DDE (ng/L)			Endrin (ng/L)			Endosulfan II (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	nd	0.562	N/A	nd	nd	N/A	nd	3.708	N/A	303.991	29.119	90
13.1 m	14.457	25.214	-74	nd	nd	N/A	5.522	9.380	-70	nd	3.484	N/A
16.4 m	15.467	nd	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	1.969	-62	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	1.998	6.691	-235	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Sand												
8.5 m	nd	5.892	N/A	nd	nd	N/A	nd	8.576	N/A	303.991	16.362	95
13.1 m	14.457	22.755	-57	nd	nd	N/A	5.522	nd	100	nd	3.408	N/A
16.4 m	15.467	0.895	94	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	4.453	-267	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	1.998	1.057	47	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Gunderboom Fabric												
8.5 m	nd	3.328	N/A	nd	nd	N/A	nd	6.924	N/A	303.991	4.498	99
13.1 m	14.457	22.441	-55	nd	nd	N/A	5.522	nd	100	nd	nd	N/A
16.4 m	15.467	1.945	87	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	2.955	-143	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	1.998	1.253	37	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
EMCON Fabric												
8.5 m	nd	16.015	N/A	nd	nd	N/A	nd	1.406	N/A	303.991	15.294	95
13.1 m	14.457	16.202	-12	nd	nd	N/A	5.522	nd	100	nd	nd	N/A
16.4 m	15.467	nd	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
20.6 m	1.215	2.886	-138	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
25.0 m	1.998	2.331	-17	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

PESTICIDES (Continued)

SAMPLE GROUP NAME	4,4'-DDD (ng/L)			Endrin Aldehyde (ng/L)			Endosulfan Sulfate (ng/L)			4,4'-DDT (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand												
8.5 m	nd	nd	N/A	nd	3.339	N/A	1.935	nd	100	nd	9.018	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	13.791	46.667	-238
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	1.163	nd	100
20.6 m	nd	6.939	N/A	nd	nd	N/A	nd	2.523	N/A	2.206	nd	100
25.0 m	2.730	nd	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Peat-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	1.935	3.911	-102	nd	0.603	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	13.791	21.371	-55
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	1.163	3.820	-228
20.6 m	nd	1.774	N/A	nd	nd	N/A	nd	nd	N/A	2.206	nd	100
25.0 m	2.730	nd	100	nd	nd	N/A	nd	nd	N/A	nd	0.401	N/A
Zeolite-Sand												
8.5 m	nd	nd	N/A	nd	nd	N/A	1.935	nd	100	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	2.057	N/A	13.791	21.050	-53
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	1.163	1.726	-48
20.6 m	nd	4.793	N/A	nd	nd	N/A	nd	1.332	N/A	2.206	3.989	-81
25.0 m	2.730	nd	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Compost-Sand												
8.5 m	nd		N/A	nd		N/A	1.935		100	nd		N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	13.791	20.122	-46
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	1.163	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	2.206	nd	100
25.0 m	2.730	2.502	8	nd	nd	N/A	nd	3.512	N/A	nd	nd	N/A
Enretech-Sand												
8.5 m	nd	11.351	N/A	nd	5.188	N/A	1.935	5.910	-205	nd	13.946	N/A
13.1 m	nd	3.377	N/A	nd	11.131	N/A	nd	2.527	N/A	13.791	28.494	-107
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	1.163	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	2.206	nd	100
25.0 m	2.730	nd	100	nd	nd	N/A	nd	2.600	N/A	nd	0.619	N/A

PESTICIDES (Continued)

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

SAMPLE GROUP NAME	4,4'-DDD (ng/L)			Endrin Aldehyde (ng/L)			Endosulfan Sulfate (ng/L)			4,4'-DDT (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand												
8.5 m	nd	42.117	N/A	nd	25.459	N/A	1.935	2.837	-47	nd	2.183	N/A
13.1 m	nd	5.417	N/A	nd	7.334	N/A	nd	1.522	N/A	13.791	46.242	-235
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	1.163	nd	100
20.6 m	nd	1.434	N/A	nd	nd	N/A	nd	nd	N/A	2.206	6.997	-217
25.0 m	2.730	nd	100	nd	nd	N/A	nd	nd	N/A	nd	3.797	N/A
Sand												
8.5 m	nd	92.215	N/A	nd	1.030	N/A	1.935	1.984	-3	nd	nd	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	13.791	nd	100
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	1.163	nd	100
20.6 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	2.206	3.682	-67
25.0 m	2.730	nd	100	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A
Gunderboom Fabric												
8.5 m	nd	4.559	N/A	nd	nd	N/A	1.935	2.691	-39	nd	1.592	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	13.791	nd	100
16.4 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	1.163	nd	100
20.6 m	nd	1.475	N/A	nd	nd	N/A	nd	nd	N/A	2.206	6.876	-212
25.0 m	2.730	nd	100	nd	nd	N/A	nd	nd	N/A	nd	0.978	N/A
EMCON Fabric												
8.5 m	nd	6.713	N/A	nd	nd	N/A	1.935	3.499	-81	nd	35.535	N/A
13.1 m	nd	nd	N/A	nd	nd	N/A	nd	nd	N/A	13.791	10.853	21
16.4 m	nd	3.912	N/A	nd	nd	N/A	nd	nd	N/A	1.163	1.571	-35
20.6 m	nd	2.220	N/A	nd	nd	N/A	nd	nd	N/A	2.206	3.788	-72
25.0 m	2.730	nd	100	nd	nd	N/A	nd	nd	N/A	nd	3.566	N/A

FILTRATION MEDIA EVALUATION: PreSettled Influent

Fall 1995

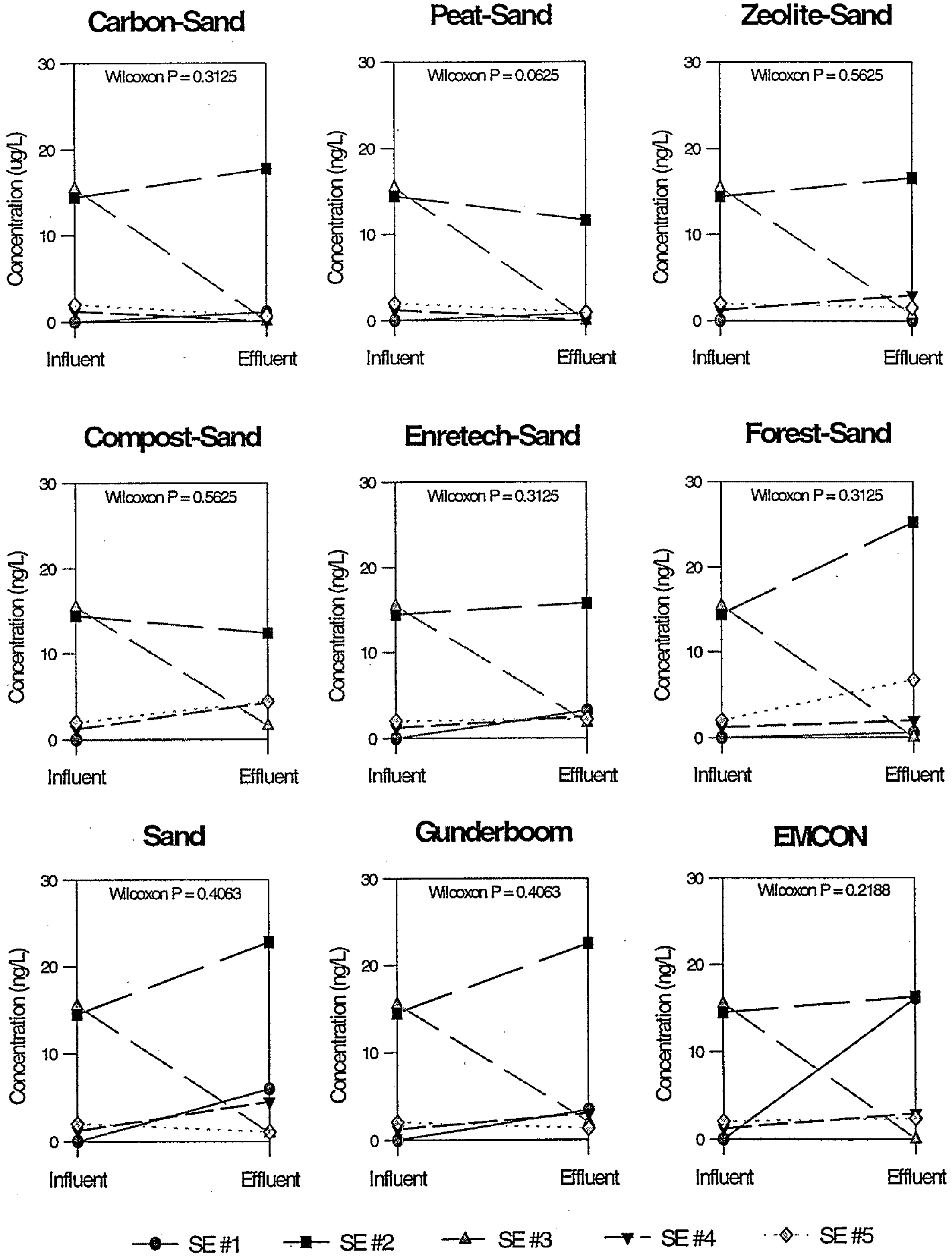
PESTICIDES (Continued)

SAMPLE GROUP NAME	Endrin Ketone (ng/L)			Methyoxychlor (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Activated Carbon-Sand						
8.5 m	2.403	1.249	48	13.133	nd	100
13.1 m	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A
Peat-Sand						
8.5 m	2.403	1.752	27	13.133	15.052	-15
13.1 m	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A
Zeolite-Sand						
8.5 m	2.403	nd	100	13.133	nd	100
13.1 m	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A
Compost-Sand						
8.5 m	2.403		N/A	13.133		N/A
13.1 m	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A
Enretech-Sand						
8.5 m	2.403	nd	100	13.133	35.629	-171
13.1 m	nd	1.526	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A

FILTRATION MEDIA EVALUATION: PreSettled Influent
Fall 1995

PESTICIDES (Continued)

SAMPLE GROUP NAME	Endrin Ketone (ng/L)			Methyoxychlor (ng/L)		
	Influent	Effluent	% Decrease	Influent	Effluent	% Decrease
Forest Products-Sand						
8.5 m	2.403	6.272	-161	13.133	43.607	-232
13.1 m	nd	1.292	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A
Sand						
8.5 m	2.403	nd	100	13.133	2.647	80
13.1 m	nd	nd	N/A	nd	6.417	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A
Gunderboom Fabric						
8.5 m	2.403	nd	100	13.133	38.314	-192
13.1 m	nd	nd	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A
EMCON Fabric						
8.5 m	2.403	1.577	34	13.133	35.754	-172
13.1 m	nd	9.235	N/A	nd	nd	N/A
16.4 m	nd	nd	N/A	nd	nd	N/A
20.6 m	nd	nd	N/A	nd	nd	N/A
25.0 m	nd	nd	N/A	nd	nd	N/A



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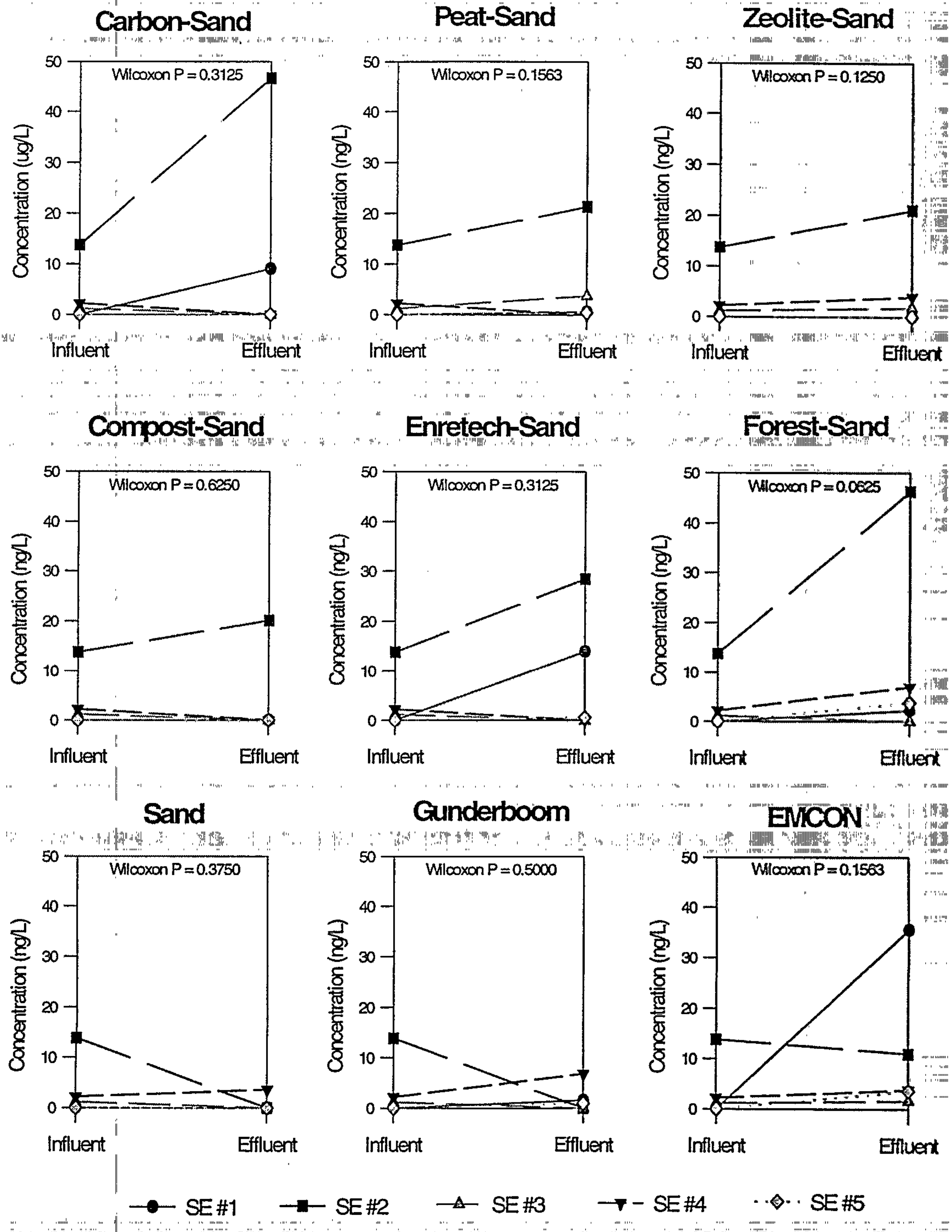

4,4'-DDT: PreSettled Influent

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