Crushed Glass as a Filter Medium for the Onsite Treatment of Wastewater

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FINAL REPORT

Prepared for

CWC

Formerly known as the **Clean Washington Center,**

a division of the Pacific Northwest Economic Region (PNWER)

999 Third Avenue, Suite 1060

Seattle, Washington 98104

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Prepared by

Aqua Test, Inc. and Stuth Co., Inc.

P.O. Box 950

Maple Valley, Washington 98038

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CRUSHED GLASS AS A FILTER MEDIUM FOR THE ONSITE TREATMENT OF WASTEWATER

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

A demonstration project was to test, monitor, and evaluate the use of crushed recycled glass for the biological treatment of residential wastewater. The primary focus of this study was a direct comparison between two biological filters; the first using the state standard C-33 sand* as the treatment medium, and the second using crushed recycled glass.

The objective of this study is to seek approval to use crushed recycled glass in place of sand for intermittent sand filters from the Washington State Technical Review Committee. The reason for this effort is two-fold. First, the state of Washington has large stockpiles of recovered glass that do not presently have a viable market. Second, sand of suitable quality for filter construction is not available in all areas of the state and a substitute material needs to be identified. An important concern for this project was the cost of the material. Therefore, the processing of this material was kept to a minimum.

Sand filters have been proven to be an effective way to treat effluent from residential septic tanks. The discharge from most residential intermittent sand filters is three times cleaner than what is discharged from a typical municipal treatment facility.** In addition, the effluent from the sand filter is directed to a drainfield for final treatment and disposal, whereas a municipal plant typically discharges to surface water.

Two systems were installed for this study; one a split filter, which is effectively two filters that are side by side. This system compares the C-33 sand to a glass material crushed to a similar specification. The two halves of the split filter were loaded with waste from a single family home on an equivalent flow basis. The filters were monitored for two years and the output was analyzed for various biological and chemical parameters to evaluate the performance of the two filters. Based upon the data collected to date, the glass performed as well as the sand in the split filter system. The second year of the study focused on the split filter only.

* C-33 is the state sieve standard for sand to be used in intermittent sand filters. The actual sand and crushed glass used in this study is slightly coarser than the C-33 specification.

A second system was installed using only the crushed glass material. This was a much smaller filter, with a loading rate higher than what is generally accepted for sand filter construction in Washington State. In addition, this filter was an above ground installation in Eastern Washington. This filter failed because of cold weather inhibiting the biological action. It is not believed that the failure of this filter had anything to do with the material used.

In August 1996 the Washington State Onsite Wastewater Technical Review Committee approved the use of waste glass, crushed to the C-33 specification, for the use in sandfilter construction.

The use of glass in treatment filters has a demand that could use all the excess waste glass produced in the state. In addition, the development of portable crushers for rural collection sites could provide a local market for the glass, because glass is not cost effective to transport to regional recycling facilities. This local crushing could provide suitable filter material in areas where it is presently not available.

The value of this material for the biological filtration ranges from $10 to $20 per yard. The approximate cost for processing this material is $10 to $15 per yard. One yard equals approximately one ton.

** Based on a secondary treatment standard for municipal discharge (30 mg/L - BOD_5, 30 mg/L TSS) as compared to an intermittent sand filter with a design load rate of 1.2 gallon/ft^2 (C-33 sand).

1.0 BACKGROUND TO THE GLASS MEDIUM WASTEWATER FILTER STUDY

Septic systems in America have been given a bad name, generally perceived as a method of disposal rather than treatment. However, because of the escalating cost of centralized sewer systems, septic systems with improved treatment capabilities are attractive as a less costly and more effective treatment and disposal alternative. This report explores the potential benefits of using crushed recycled glass as filter medium in modern septic treatment and disposal systems.

1.1 SEPTIC SYSTEMS

Historically, septic systems were used in rural areas and in suburbs where they were installed as a temporary solution until the sewers were extended or where population densities were expected to remain low. A standard septic system reduces the five day Biochemical Oxygen Demand (BOD_5) from 30 to 70% and the Total Nitrogen level from 30 to 40%.[1] This level of treatment is acceptable when good soils, which can complete the treatment or disposal process, are present, and lot sizes are large enough to accommodate a system. However, building lots with good soils for standard septic systems are scarce and questions have been raised regarding the potential for groundwater contamination from standard systems in certain site conditions. Current estimates show that 70% of the water pollution in the state of Washington comes from nonpoint sources, such as leaking underground fuel storage tanks, surface water run off, and leaking sewer lines and septic systems. In contrast, a properly installed septic system in good soils has negligible effect on the environment.

Modern trends have also placed a greater demand on residential sewage treatment systems. Although a dual income family may use the same amount of water as a single income family, they use water during a more restricted time frame, placing greater surge loads on the system. In addition, the increased use of plant oils for cooking (olive, corn, etc.) rather than fats and shortening increases the likelihood of the oils carrying through the septic tank to the drainfield where they may contribute to system failure.

Historically, standard septic systems were allowed in some suburbs because they were viewed as a temporary measure until the central sewer collection lines were extended to that area. However, the cost of centralized sewers has escalated, government funds have diminished, siting central treatment plants has become more difficult, and the quality of treatment of these facilities has been questioned.

These costs and environmental concerns are triggering a more wide-spread implementation of advanced onsite treatment and disposal systems. These systems have a greater treatment capability than standard septic systems and most central treatment facilities. The two main non-proprietary aerobic treatment systems are the sand mound and the sand filter. Between January 1990 and August 1993, 34% of all on-site sewage treatment and disposal systems installed in King County, Washington State's most heavily populated county, were either sand filters or sand mounds.[2]

1.2 SAND FILTER SYSTEMS

A sand filter residential sewage treatment system generally consists of a standard septic tank, a sand filter and a disposal system (drainfield). The septic tank allows the settling solids and the floatable scum to be removed from the flow. The septic tank effluent is then dosed evenly over the sand, which acts as a biological filter. Generally, the sand filter is lined and the effluent is directed to the drainfield for final treatment and disposal. The loading rate for a sand filter under Washington State Code is 1.2 gallons per square ft per day. The loading rate for the soils varies with the soil type. A properly installed and maintained sand filter generally produces an effluent with a BOD_5 less than 10 mg/L and Total Suspended Solids (TSS) of less than 10 mg/L.[1,3,4,5,6]

The placement of a sand filter is flexible as it can be placed above or below the ground surface and its size is not dependent on the local soil conditions. A pump is normally required to lift the effluent from the septic tank to the sand filter and an additional pump may also be required to distribute the effluent to the drainfield.

2.0 FILTER MATERIALS AND SAMPLE PROTOCOL

This section reviews the various materials used in this study as well as the tests that were performed on both the filter materials and the system influent and effluent.

2.1 C-33 SAND

Both sand filters and mound systems utilize sand as the biological filter medium. The standard specification for this medium in the state of Washington is ASTM C-33 sand. Although typically called a filter, the sand is not simply a mechanical filter. The sand slows the flow of the effluent and at the same time provides a home for the micro-organisms which breakdown the organic matter, remove pathogens, and convert Ammonia to Nitrate.

The typical cause for sand filter failure is the development of a mat of biological material, commonly called a biomat. One way an excessive biomat can build is through the formation of lenses of fine material (< NO. 100 sieve) in the filter element. As the effluent flows through the filter medium, it segregates the fines from the coarse material and deposits the fine material in lenses. These lenses then restrict the movement of effluent through the filter, encouraging the formation of a biomat. Eventually the filter clogs, requiring repair.

Under the C-33 sand guidelines, up to 10% of the material may be finer than a 100 sieve, thus providing a ready source of fines for the formation of a lens. Some counties in Washington State have modified their standard by reducing the amount of fines allowed under the C-33 standard. Other counties require wet sieving, which more accurately defines the quantity of finer materials. It defines them by washing them off the larger grains and it also breaks-up any peds (clods) of fine materials, which might not have been otherwise quantified as fines. Reducing the quantity of fine material should reduce the frequency of filter failures.

In addition to the problem with fines, sand filter-quality sand is not readily available in many parts of the state (or country). The EPA notes that the availability of filter medium has the most significant impact on the construction cost of sand filter systems,[7] a major problem with tightening the specifications. A new filter medium that can further reduce the number of failures, is cost competitive, and readily available is needed in many areas of the country.

2.2 CRUSHED GLASS AS A FILTER MEDIUM

Because of the less-than-optimum performance of C-33 sand, and an over-abundance of recovered glass, the Clean Washington Center (CWC), Aqua Test Inc., and Stuth Co., Inc., formed a partnership to study the utilization of crushed recycled glass in place of C-33 sand-in-sand filter systems.

The use of glass as a filter medium has several advantages: glass can be crushed to meet different gradation specifications, glass collected by recyclers is available in every area of the country, and preliminary experimentation indicates the fine material in crushed glass could be more easily washed through the filter.[8] Glass's higher permeability may lessen the formation of lenses and the biomat associated with them.

Section 2 of this report provides information regarding the materials used in the filters and the sample protocol for this study. Sections 3 and 4 of this report address the first two glass filters installed in Washington State and the data associated with the first year of monitoring these filters. Filter Site #1 provides the opportunity to directly compare the performance of C-33 sand and crushed glass as filter medium under high waste loading conditions. Filter Site #2 was chosen to test the use of crushed glass in smaller sand filters located in harsh cold weather country.

2.3 SIEVE ANALYSIS

Appendix A contains the sieve results for the two-filter medium used (one glass and one sand). The sand material used as the control in this study was obtained from Stoneway Concrete. The company's name for this material is Concrete Sand. The material used in this study does not conform to the C-33 standard in that it has a fineness modulus of 3.30, which indicates a material at the coarse end of the C-33 spectrum. The material, which has slightly too much retained in the eight and sixteen sieve, is still very close to the C-33 standard and has the advantage of very few fines. Concrete Sand has a uniformity coefficient of 6.0, which indicates a moderate range of particle sizes. The effective size is 0.27 mm. This is the material commonly used for sand filter construction in this area and is superior to other sands, which could pass the C-33 test because of its lack of fine material.

The glass material used in this study is recycled glass crushed by Stoneway Concrete. When compared to the C-33 standard using a sieve analysis, this material also fails at the coarse end of the C-33 spectrum. Although this material does pass the C-33 standard for medium to fine grain size, the quantity of fines passing the 100 sieve (6.26%) is in excess of what is generally considered desirable for use in sand filter construction. This material has a fineness modulus of 3.65, which indicates too much coarse material (for the C-33 standard), and a uniformity coefficient of 7.8, which indicates a wider range of particle sizes than the sand used in this study. The effective size of this material is 0.24 mm.

2.4 RELATIVE INFILTRATION

The filter materials were also tested for their relative infiltration rates. The relative infiltration test was developed by Stuth Co., Inc. to measure the flow through a material under saturated conditions. This provides additional information regarding the characteristics of flow through various materials--as compared to the C-33 standard sand.

The concrete sand had a relative infiltration rate of approximately 95 seconds per inch compared to approximately 9 seconds per inch for the comparable glass material. **Table 1** presents the relative infiltration rates for the sand and the glass materials used in this study. The data from the relative infiltration tests and a detailed description of the test are provided as Appendix B.

Table 1
Relative Infiltration Rates

Material	Infiltration Rate
Concrete Sand	95 sec/inch (91.0 to 98.9 sec/inch)
Glass #1	9 sec/inch

Several materials were run for the relative infiltration tests; the glass material processed by Stoneway Concrete was used for both filters.

2.5 SITE INSPECTIONS

To ensure proper system operation the following inspections were conducted twice a month. A field check list was filled out during each inspection and the following information was recorded:

- Sludge levels and baffles in the tanks were inspected for potential clogging and/or excessive build-up. (Monthly)

- Filter inspection ports were checked for ponding and potential filter failure.

- Data was collected from the cycle counters every two weeks and pump calibrations were conducted as necessary.

- Samples were collected as outlined below under "Sample Collection, Parameters, Holding Times, and Preservation" (monthly).

2.6 SAMPLE COLLECTION, PARAMETERS, HOLDING TIMES, AND PRESERVATION

To evaluate the performance of the filters, samples of the flow to and from the filters (influent, effluent) were sampled and analyzed for the following parameters.

<u>BOD_5</u> - Biological Oxygen Demand over a five day test period. This is presented in mg/L. This represents the oxygen required by micro-organisms to oxidize (breakdown) the organic material (food or waste) suspended in a wastewater sample.

<u>TSS</u> - Total Suspended Solids measured in mg/L. This refers to the residue that is retained on a glass fiber filter disk. This can include both organic and inorganic materials. A low BOD5 and a high TSS can indicate a high concentration of inorganic suspended solids.

<u>O&G</u> - Oils and grease. Can also include fats, lotions, dead micro-organisms. A high O&G can be a major contributing factor to a failing system.

<u>Fecal Coliform</u> - An organism that may indicate the presence of other pathogenic organisms that pose a public health threat.

<u>Nitrogen</u> - A Nitrogen balance test requires the parameters of Ammonia (NH_3-N), Total Kjeldahl Nitrogen (TKN), Nitrate (NO_3) and Nitrite (NO_2). Excess Nitrogen in a surface water can

facilitate algae bloom. Excess Nitrogen in drinking water may cause methemoglobinemia (baby blue syndrome) in infants.

pH - An expression of the intensity of the alkaline or acidic strength of the water. Can be used to indicate a problem with the treatment process.

Temperature - Biological treatment of wastewater can be dramatically affected by temperature.

Dissolved Oxygen - the level of dissolved oxygen can be an indicator of the proper or improper function of an aerobic or anaerobic treatment system.

2.6.1 Sample Collection

Filter influent and effluent samples were collected monthly. To ensure that representative samples were collected, several steps were followed.

1. Sampling equipment was clean and in proper working condition before use.

2. Appropriate sampling containers were used. Sample containers were clean (or sterilized when required) and contained appropriate fixative when necessary.

3. To avoid cross contamination, the sampling device was cleaned with distilled water before collecting the next sample.

4. The filter influent sample was collected from inside the pump chamber below the liquid level for both of the systems. The intent of all sampling is to collect a sample that is representative of the flow going into the next system component.

Note: The oil & grease (O&G) sample was an aliquot from the sample collected for BOD_5/TSS. Therefore, the BOD_5/TSS sample was collected first, mixed thoroughly, then decanted into the O&G container.

5. Some field measurements required were taken from the sample bottle (pH, Temperature). However, the Dissolved Oxygen (DO) was taken from the sample source (tank). Samples

were then placed in an ice chest to maintain temperature at less than 4 degrees centigrade. The samples were then transported to a state certified laboratory before the maximum holding times had been exceeded.

2.6.2 When and Where to Sample

All systems were inspected bi-weekly and samples for laboratory analysis were collected monthly. Filter influent and effluent samples were collected as follows:

Sand Filter Dose Tank (Sand filter influent)

Samples were collected from the filter dose tank for Filter #1, and from the dose chamber of the septic/surge tank for Filter #2. Sample collection took place during the pump's mid-cycle stage (during the off time). To determine the pump's stage in the cycle, the field technician inspected the water marks on the tank walls in relation to the current liquid depth.

Drainfield Dose Tank (Sand filter effluent)

Samples were collected from the respective sample ports on the inside of the drainfield dose tank for Filter #1 and from the sample port outside the filter for Filter #2 (see filter details drawing in Appendices C and F).

2.6.3 Sample Parameters and Their Holding Times

Table 2 presents the maximum holding times for the parameters analyzed in this study. A further description of the sample parameters is provided in Appendix H, the Glossary.

Table 2
Sampling Parameters and Regulatory Holding Times
(Standard Methods 17th ed.)

Biochemical Oxygen Demand (BOD_5)	48 hours
Total Suspended Solids (TSS)	7 days
Oil and Grease (O&G)	28 days (preserved
Fecal Coliform (FC)	6 hours / 24 hours @ 4°C
Total Kjeldahl Nitrogen (TKN)	28 days (preserved)
Nitrate Nitrogen (NO_3)	48 hours

Nitrite Nitrogen (NO_2)	48 hours
Ammonia Nitrogen (NH_3-N)	48 hours
pH	2 hours
Temperature	Stat.
Dissolved Oxygen (DO)	Stat.

3.0 FILTER SITE # 1

3.1 SITE CONDITIONS

Filter #1 was installed at a private single family residence in King County, which had a history of septic system failure. The family at this site has five children and was expected to have higher wastewater flow and waste strength than is typical for a single family residence.

The site soils are Type 4 to 18 in., underlain with a compacted clay pan to 60 in. There is a history of high ground water.

The previously existing system had failed and effluent was surfacing. This system consisted of a 1,000-gallon two-compartment septic tank, which gravity fed a 1,000-gallon pump chamber. This pump pressure dosed 406 linear ft of drainfield on demand. The drainfield trenches were 24 in. wide by 9 in. deep, with 6 in. of gravel below the 1-inch lateral and 2 in. above it. The original system as-built is provided in Appendix C.

3.2 DESIGN

The filter system design utilizes a single pass intermittent filter. Appendix C provides the details of the filter and the site plan. The new system flow plan is as follows.

- Flow from the house discharges into the existing 1,000-gallon, two-compartment, septic tank.

- Effluent from the septic tank flows by gravity through a screened outlet baffle to the existing 1,000-gallon dose tank. (This tank was previously the pump tank that fed the drainfield.) The original 1-hp pump that was in this tank has been replaced by a 1/3-hp pump, which doses the sand/glass filter on demand. The demand option for dosing the filter is in accordance with current King County regulations, which do not allow more than four doses per day.

- The sand/glass filter is a two-compartment filter that measures 20 feet by 20 feet. The two-compartments are separately lined to keep the effluents and filter materials segregated. Effectively the system is two separate 10-ft by 20-ft filters fed by a common manifold. One filter utilizes the state standard C-33 sand and the second filter utilizes crushed recycled glass. The effluent is collected at the bottom of the two filters and transported to the drainfield dose tank through separate lines. The filter's design loading is 1.2 gallons per ft^2 per day.

- The drainfield dose tank is a 750-gallon, single-compartment tank with a single riser. The two lines from the sand and glass filters "T" into two six-inch stand pipes that are mounted inside the drainfield dose tank (see Appendix C). The stand pipes act as sampling test ports and have large horizontal slits in them near the top to allow the effluent to overflow into the tank and commingle. The slits are approximately 20 in. above the high-water alarm. The relocated 1-hp pump from the existing system is mounted in this tank and pressure doses the drainfield on demand.

- The system uses previously existing drainfield. It consists of a 60-ft by 4-in. manifold with eleven laterals spaced 6 ft on center. The trenches are 24 in. wide by 9 in. deep with a total of 406 ft of laterals in this drainfield.

3.3 FLOW VOLUME

The amount of septic flow to the two filters, and the waste strength of the septic tank effluent and the filter effluent, are a measure of the performance demand placed on the system. Please refer to Appendix D.

As previously mentioned, this system was installed at a single family residence. However, this is not a typical single family residence. There are several children present during the day and the flows for this site are higher than what would be expected of a typical residence. For the 2 ½ years this system was studied, the average flow was 473 gallons per day (GPD). This includes the winter flows that exceeded 1,400 GPD for one two-week period. It is our understanding that the winter flows were high because of water being continuously run to prevent the home's pipes from freezing. Groundwater infiltration into the tanks may have also been a factor in causing the high flow rates.

Flow data were recorded twice per month. **Table 3**, Waste Strength Data for the Glass & Sand Filter, presents the average monthly flows for this site along with the waste strength data for the filter influents and effluents. This information is based on data collected from February 1994 to February 1995, and from November 1995 to December 1996. The complete data base for Filter #1 is provided in Appendix D.

The loading for the filter varied during the study from 0.7 to 3.7 gallons per ft^2 per day. The average load was 1.2 gallons per ft^2 per day, compared to the filter's design loading of 1.2 gallons per ft^2 per day, the Washington State Code design limit. Although this matches the design limit for a typical sandfilter installation, most residential filters do not actually receive this high of a hydraulic load.

3.4 WASTE STRENGTH

3.4.1 Septic Tank Effluent (Filter Influent)

The waste strength data refers to the Biochemical Oxygen Demand (BOD_5 - five day test), Total Suspended Solids (TSS), and Oil and Grease (O&G). As noted in 2.2.3 above, these samples were collected and analyzed monthly.

The residence was found to have a slightly higher waste strength than a typical single family home. The average BOD_5, TSS, and O&G for the septic tank effluent (filter influent) for this system over two years was 168 mg/L, 47 mg/L, and 27 mg/L respectively. Most references consider a BOD_5 range of 120 mg/L to 180 mg/L typical for effluent from a single family residential septic tank and should be closer to the low end of this range coming out of a screened outlet baffle.[4] The high BOD_5 recorded during this study was 264 mg/L with the low BOD_5 being 43 mg/L. The low BOD_5 value was recorded during a high flow event.

Table 3
Waste Strength Data for Glass and Sand Filter #1

Source	GPD	Filter Loading	BOD_5	TSS	O&G	pH	Temp.
Septic Tank Effluent (Filter Influent)	473	1.2	168	47	27	6.7	16
Glass Medium Effluent (Filter A)			7 (96%)	4 (91%)	6 (79%)	6.4	13
C-33 Sand Effluent (Filter B)			4 (98%)	3 (94%)	4 (86%)	5.8	12

(%) - Percent Reduction
BOD, TSS, and O&G are reported as mg/L
GPD - Average of data collected biweekly
Start-up data from 2/23/95 not used in averages
Filter loading reported as Gallons/ft^2/day

The TSS averaged 47 mg/L with a high of 80 mg/L and a low of 15 mg/L. There is very little published information on TSS for residential septic tank effluent. However, a paper published by Orenco systems of Roseburg, Oregon, reports an average TSS of 26.1 mg/L from a single-compartment tank with a screened outlet baffle, similar to what is installed on the septic tank outlet of this system.

The Oil & Grease averaged 27 mg/L with a high of 41 mg/L and a low of 12 mg/L. Again, very little data is available on the typical O&G level for the effluent from a single family septic system. It has been the experience of Stuth Co. and Aqua Test Inc. that O&G levels range from 15 to 25 mg/L in typical residential septic tank effluent.

3.4.2 Filter Effluent

As shown in **Table 3**, the sand filter out-performed the glass filter by a slight margin for the BOD_5 and TSS parameters. The sand filter BOD_5 averaged 4 mg/L for a 98% reduction and the TSS averaged 3 mg/L for a 94% reduction. The glass filter BOD_5 averaged 7 mg/L for a 95%

reduction and the TSS averaged 4 mg/L for a 89% reduction. The data, from both filters, are generally consistent with data reported by others on intermittent sand filter performance.[1,3,4,5,6]

The O&G results are again very close. The Glass filter averaged 6 mg/L for a 79% reduction while the sand averaged 4 mg/L for an 86% reduction.

The pH and temperatures were all within normal ranges; however, the sand consistently produced a more acidic effluent than the glass filter. It is not believed that temperature played a significant role at this site with the recorded temperatures ranging from 6º C to 19º C (43º F to 66º F). The data suggests the filters produced their best effluent during the warmer months.

Considering the strength of the filter influent and the volume of waste flow applied, the overall performance of both filters was exceptional, with the sand filter only slightly out-performing the glass filter for the BOD_5, O&G and TSS parameters. Based on the number of samples collected, the minor differences in results would not be considered significant.

Because of the high quality of effluent discharged by the glass/sand filter the drainfield completely recovered in the first year with no additional repair being done.

3.5 COLIFORMS AND NITROGEN

3.5.1 Fecal Coliforms

The septic tank effluent averaged 701,000 coliform units/ 100 mls (CFU/100 ml), with a high of 2.7 million and a low of 70,000 CFU. The sand filter produced an average coliform count of 514 CFU/100 ml for a 99.9% reduction. The glass filter produced a 99.8% reduction with an average count of 1640 CFU/100 ml. The data for Filter Site #1 is presented in **Table 4**, Nitrogen & Fecal Coliform Data from Glass and Sand Filter #1.

Table 4 Nitrogen and Fecal Coliform Data for Glass and Sand Filter #1					
Source	Fecal Coliform	TKN	NH_3-N	NO_2	NO_3
Septic Tank Effluent (Filter Influent)	701,000	41	37	<1	<1
Glass Medium Effluent (Filter A - 48% reduction of Total Nitrogen)	1640	1.9	<1	<1	28
C-33 Sand Effluent (Filter B - 32% reduction of Total Nitrogen)	514	2.4	<1	<1	28

Fecal Coliforms reported as CFU/100 ml. Start-up data from 2/23/94 and 3/15/94 not used in fecal averages. TKN, Ammonia, Nitrate and Nitrite are reported as mg/L Nitrogen. Nitrogen reduction is based on data from 5/17/94 to 2/08/95.

3.5.2 Nitrogen

To evaluate the total nitrogen reduction for the filters influent and effluent samples were analyzed for Total Kjeldahl Nitrogen (TKN), Ammonia (NH_3-N), Nitrite ($N0_2$) and Nitrate (NO_3). All the parameters are reported as Nitrogen (N). As shown in Appendix D, the production of nitrifying bacteria took between one and two months. By the third month a near complete conversion from Ammonia to Nitrate was being accomplished in both halves of the filter.

Based on the average data being collected once the nitrifying bacteria were established, the sand filter produced a 27% reduction in Total Nitrogen and the glass filter averaged a 29% reduction.

4.0 FILTER SITE # 2

During the first year of the study Filter #2 failed because of cold weather. After the filter failed attempts were made to repair the filter. Although the initial repairs were successful, the filter again failed due to cold weather during the second winter. During the summer of 1996 an aerobic pretreatment unit (Nibbler Jr.) was installed in the outlet of the septic tank. This unit pretreats the effluent from the septic tank before being dosed to the sandfilter and controls the flow rate to the filter. The study of this filter will continue for years to come.

The following information relates to Filter #2 during the first year of operation prior to the filters cold weather failure. The data base in Appendix G provides the data collected over the last 2 ½ years.

4.1 SITE CONDITIONS

The site is located approximately 10 miles northwest of Cle Elum, Washington, in the town of Ronald. The site contains a single family residence that had a failing pressurized drainfield. The properties in this area sit in a lowland/drainage basin. Ground water reaches the ground surface during the wet season in some areas on this site. The soils are a sandy clay loam Type 6 soil. The hydrometer results are provided in Appendix E.

The previous system was a two-compartment 1,000-gallon tank, followed by a pump tank that pressure-dosed a drainfield on an adjacent piece of property. This system had a serious ground water infiltration problem, which caused a hydraulic overload of the existing drainfield.

Occupancy at this site varies from 2 adults to 4 adults and one child. The wastewater flows were anticipated to be approximately 200 GPD with a max. BOD_5 of 200 mg/L.

4.2 DESIGN

The components of the new system (designated as Filter #2) are described below. Appendix F, the Filter site #2 as-built drawing, depicts these components.

- Flow from the house discharges into a new 1,620-gallon, single-compartment septic tank.

- A high head/low flow turbine pump mounted in a screened vault inside the septic tank pressure doses an 11-ft by 11-ft glass filter. This pump is controlled by a programmable timer. This feature allows this tank to operate as a surge tank and doses the glass filter over a 24-hour period rather than on demand. The primary components of this system (pump, control panel, risers, filter liner, manifold, laterals and collection line) were from a kit provided by Orenco System Inc. of Roseburg, Oregon.

- The glass filter is a single-compartment filter that measures approximately 11 ft by 11 ft. The filter is built above ground in a cinder block frame and is lined using a 30 ml. poly liner. The profile from the top to bottom is 6 in. of pea gravel, 24 in. of crushed glass, 3 in. of pea gravel, and 6 in. of drain rock. An air manifold is installed at the bottom of the glass layer to assist in aerating the system if necessary. The effluent is collected at the bottom of the filter and gravity flows to a sample port immediately outside the filter. A sample port is also provided in the filter to inspect any potential ponding.

- The sample port, outside the filter, is a T'ed 6-in. by 4-in. stand pipe, which allows inspection and sampling of the filter effluent.

- The drainfield for this system is a series of three gravity lines that are stepped as shown on the system as-built. The first gravity trench is 28 ft long, the second is 35 ft and the third is 16 ft. Each line has an inspection port near the end to monitor any ponding and the condition of each trench. A typical cross section of the trench is provided on the system as-built. (Appendix F)

- If the final disposal trench ponds above the final step down, an overflow line allows excess effluent to flow by gravity to the old system's pump tank, which, in turn, would pressure dose the old drainfield on demand.

The system has now been modified. A Nibbler Jr. aerobic pretreatment unit is mounted at the outlet of the septic tank. This unit discharges to a new 30 in. pump vault mounted outside the septic tank. The pump in this vault doses the filter on demand. The panel for time control has been removed and the Nibbler Jr. now provides the time control for the flow.

4.3 FLOW VOLUME

Flow data were recorded twice per month. **Table 5** presents the average monthly flows for this site along with the waste strength data for the filter influent and effluent. The information in

Section 4 is based on data collected from June 1994 to July 1995. The complete data base is provided in Appendix G.

This system was installed with a turbine pump without a check valve. Before installing a check valve in May 1995, each time the pump cycled some of the effluent in the transport line would flow back to the septic tank. The flows recorded after May 1995 are believed to be representative of the system conditions, averaging 193 GPD. This value was used as an assumed average for the soil and filter loading prior to the check valves installation.

Table 5 Waste Strength Data for Glass Filter #2							
Source	GPD	Filter Loading	BOD_5	TSS	O&G	pH	Temp.
Septic Tank Effluent (Filter Influent)	193	1.6	243	59	48	7.8	17
Glass Medium Effluent (Filter A)			7 (97%)	4 (94%)	7 (85%)	7	16

(%) - Percent Reduction.
BOD, TSS, and O&G are reported as mg/L.
GPD - Average of data collected biweekly.

Data collected after the failure (11/1/94 to 7/26/95) are not used in averages.
Filter loading reported as Gallons /ft^2 /day.

4.3.1 Filter Loading Rate

The hydraulic loading on this filter ranged from 1.4 to 2.1 gallons per ft^2 per day. Based on an average hydraulic load of 193 GPD and a BOD_5 of 243 mg/L the average biological load on this filter was 0.0032 lb/ft^2/day. A typical biological load on this filter utilizing 193 GPD and 140 mg/L would be 0.0018 lb/ft^2/day or about half of what is being loaded on this filter.

Samples of the filter influent were collected and analyzed monthly. This residence was also expected to have a higher waste strength than a typical single family home.

4.4 WASTE STRENGTH

4.4.1 Septic Tank Effluent (Filter Influent)

The average BOD_5, TSS, and O&G for the filter influent were, 243 mg/L, 59 mg/L, and 48 mg/L respectively. Please refer to **Table 5**. Most references consider 120 mg per liter to 180 mg. per liter a typical BOD_5 range for effluent from a single family residential septic tank. Tanks with a screened outlet baffle should be at the lower end of this range (4) and a screened pump vault is installed on this system. The high BOD_5 recorded during this study was 347 mg/L with the low BOD_5 being 165 mg/L.

The TSS averaged 59 mg/L for the year with a high of 86 mg/L and a low of 30 mg/L. The Oil & Grease averaged 48 mg/L for the year with a high of 82 mg/L and a low of 29 mg/L.

Based on this information the flow from this residence is considered higher strength than typical residential septic tank effluent.

4.4.2 Filter Effluent

This filter experienced a cold weather failure. This filter was installed above ground, without insulation. As the temperature dropped, the aerobic organisms that perform the treatment function, either died-off or became dormant. The filter ceased to function as biological filter, and the filter effluent quality degraded. It is not believed that the filter loading rate or the filter material had a significant **(any)** effect on the filter failure.

Before failure, the filter operated well. The filter effluent averages and percent reduction calculations are based on data collected before the filter failed. The glass filter effluent had an average BOD_5 of 7 mg/L, for a 97% reduction and the TSS averaged 4 mg/L for a 93% reduction. This data is generally consistent with data reported by others on intermittent sand filter performance.[1,3,4,5,6] The O&G averaged 7 mg/L for a 86% reduction.

As the year progressed and temperature dropped, the filter effluent quality deteriorated. The first major change occurred when the temperature dropped below 7°C (45°F) and the nitrifying bacteria stopped converting ammonia to a nitrate form of nitrogen. Next the BOD_5 began to climb, indicating the biological activity in the filter was continuing to deteriorate. On January 18, 1995 the filter was covered with an insulating blanket. Although the temperatures stabilized, they were still too cold for effective treatment and the filter effluent quality continued to deteriorate, and the filter began ponding.

On April 4, 1995, the insulating blanket was removed and on May 4, 1995, a filter recovery procedure was initiated. Once the filter recovery procedure was completed the filter effluent quality improved and the filter stopped ponding. However, the filter continued to discharge an effluent of substandard quality.

Approximately two months after performing the filter recovery procedure, the quality of the filter effluent improved dramatically. This improvement signified a complete recovery of the biological action. A sample collected on 7/26/95 showed a BOD_5 of 12.9 mg/L, which indicated the bacteria had re-established a suitable colony for treatment.

The pH data recorded were all within normal ranges; however, the pH for the filter influent was slightly basic.

4.5 COLIFORMS AND NITROGEN

Again, the filter effluent averages and the percent reduction calculations are based on the data collected prior to the cold weather failure.

4.5.1 Fecal Coliforms

The septic tank effluent averaged 5,039,728 coliform units/ 100 mls (CFU/100 ml), with a high of 24 million and a low of 43,000 CFU. The glass filter produced a 99.96% reduction with an average effluent count of 2,268 CFU/100 ml. This data is presented in **Table 6**, Nitrogen & Fecal Coliform Data for Glass Filter #2.

4.5.2 Nitrogen

As with Filter Site #1, the production of nitrifying bacteria took between one and two months. By the end of the second month, a near complete conversion from Ammonia to the Nitrate form of Nitrogen was being accomplished by the organisms in the filter.

Table 6

Nitrogen and Fecal Coliform Data for Glass Filter #2					
Source	Fecal Coliform	TKN	NH_3-N	NO_2	NO_3
Septic Tank Effluent (Filter Influent)	5,039,728	56.2	45.9	0.1	0.3
Glass Medium Effluent (48% reduction of Total Nitrogen)	2,268	3.8	2.1	0.2	25.8

Fecal Coliforms reported as CFU/100 ml. Start-up data from 2/23/94 and 3/15/94 not used in fecal averages. TKN, Ammonia, Nitrate, and Nitrite are reported as mg/L Nitrogen. Nitrogen reduction is based on data from 8/9/94 to 11/01/94.

Based on the data collected from 8/9/94 to 11/1/94, the glass filter averaged a 47.7% reduction in Total Nitrogen. At 7º C (45º F) the filter was still converting some of the Ammonia to Nitrate. However, when the temperature hit 2º C this nitrogen conversion had been drastically reduced and two months later no conversion was taking place.

4.6 DRAINFIELD

As mentioned earlier, the soils at Filter Site #2 are a Type 6 Sandy Clay Loam. The drainfield was installed with step-downs to monitor the amount of soil area reached by the filter effluent. Type 6 soils are not considered suitable for the discharge of wastewater in some counties and the step-downs were used to document how much soil area was required to dispose of the filter effluent.

Figures 1 through **5** detail the relationship between the ponding in the drainfield and the ground water table. **Figure 1** shows a profile of the drainfield at the time of installation. At this time there was no ground water present at 7 feet below grade. Between June 29, 1994, and November 15, 1994, the elevation of the ground water rose (**Figure 2**). During this time the soil loading rate varied between 2.3 and 1.1 gallon/ft^2/day. A site inspection on November 15, 1994, showed groundwater present in the third leg of the drainfield (**Figure 3**). Groundwater elevation continued to rise until all three trenches were ponded (**Figure 4**). The three trenches remained ponded until

May 1995 when the ground water subsided. The assumed loading rate at this time was 0.85 gallon/ft^2/day. The filter effluent is currently being handled by the first two trenches, despite the relatively high waste strength discharged by the filter from February to July (**Figure 5**). The approximate loading rate for the soil from May to July is 1.1 gallon/ft^2/day.

At no time during this study did effluent surface in the drainfield. This would indicate a Type 6 soil may be suitable for the discharge of filter effluent. However, a longer term evaluation would be required to verify this conclusion.

5.0 SUMMARY

Based on the data gathered from this test comparison, glass crushed to a C-33 standard appears to be a suitable substitute for sand in standard sand filter design. In Filter #1, the sand material produced a slightly better result than the glass material for BOD_5, TSS, O&G and Fecal Coliforms reductions. However, the glass material produced slightly better results for Nitrate reduction. In addition, the crushed glass may provide other benefits relating to the long term operation and maintenance of these systems.

Although Filter #2 experienced a failure because of the cold weather, the results of this study are very encouraging. Prior to the failure, the filter produced a high quality effluent, with BOD_5, TSS and O&G all averaging less than 10 mg/L. A standard 20-ft by 20-ft sand filter will typically produce an effluent with a BOD_5 of less than 10 mg/L.

After the filter failed, it was recovered, which may indicate the glass material is more forgiving than an equivalent sand material. Further testing on other failed glass and sand filters will provide better data regarding filter recovery and material forgiveness.

Based on the data collected in this study, crushed glass has been approved as a substitute for sand in sand-filter treatment systems.

5.1 ADDITIONAL FINDINGS

As mentioned at the beginning of this report, Filter #1 was installed at a site that had a previously failed pressure dose field (surfacing effluent). The sand-and-glass filter effluent has improved the performance of the drainfield significantly and no effluent surfaces. In addition no odors are now present and the risk to public health has been greatly reduced. It should also be noted that the empty lot next door to the site also has ground water present at the surface during significant rainfall events.

The soils at the site for Filter #2, which are considered not suitable for receiving septic tank effluent in some counties, accepted the glass filter effluent at a relatively high hydraulic loading rate. Never, during this study, did effluent surface in this drainfield.

The combination producing an effluent of this quality and dosing it in shallow drainfields is an important step in being able to **recycle waste water** from a residence in a cost effective manner.

6.0 OTHER STUDIES

Several 10-ft by 10-ft to 15-ft by 15-ft high-rate filters were installed in British Columbia, Canada from 1993 to 1994. All the filters utilize a 4-50 material, that is, all the filter material sieves out between the range of a number 4 and a number 50 sieve. Several of these high rate filters contained recycled glass ground to the 4-50 standard. The flow to the glass filters ranged from an average of 140 GPD to approximately 300 GPD, with average loading rates that ranged from 1.4 gallon/ft^2/day to 2.9 gallon/ft^2/day. These filters were studied for approximately one year. Laboratory analysis of the filter influent and effluent showed an average reduction in BOD_5 of 96% and an 89% reduction in TSS. Based on 29 samples the average BOD_5 out of the filter was 10 mg/L with an average TSS of 6 mg/L.

In regards to the glass material, the project summary states, "So far there is no clear indication that the glass is any better or worse than sand medium. There are several reasons for preferring glass however, including much higher infiltration capacity and pore space, cleanliness and use of a low value recycled product."

7.0 ACKNOWLEDGMENTS

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1. Stuth, Co.
2. Aqua Test, Inc.
3. Stoneway Concrete Products, Inc.
4. Orenco Systems, Inc.

8.0 REFERENCES

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APPENDIX A

Sieve Analyses

APPENDIX B

Relative Infiltration Data and Description

Relative Infiltration Rates for Sand and Glass

Column #1

Run	**Media**	**Time (Sec.)**	**Inches**	**Infiltration sec./inch**
1		15.5	3	5.2
2	Refined Gass	20.9	4	5.2
3	(Canadian Glass)	22.3	4	5.6
4	Not used in filters	24.3	4	6.1
5		23.7	4	5.9
6		23	4	5.8
7		22.5	4	5.6
Average		21.7		5.6

Column #1

Run	Media	Time (mm..)	Inches	Infiltration sec./inch
1	Stoneway	6.41	4	96.2
2	Concrete Sand	7.57	4.5	100.9
3	(Barrons fiter)	7.26	4.5	96.8
4		7.56	4.5	100.8
5		8.4	5	100.8
6		7.35	4.5	98.0
Average		7.43		98.9

Column #2

Run	Media	Time (sec.)	Inches	Infiltration Sec/inch
14*		35.4	4	8.9
15	Stoneway Glass	35.3	4	8.8
1 6	(Both filters)	35.4	4	8.9
Average		35.4		8.8

*13 previous runs were made on this material the first run averaged 9.7 sec. per inch
and they continued to get faster with each run. The infiltration rate settled out around the 11th run.

Column #2

Run	Media	Time (mm..)	Inches	Infiltration sec./inch
1	Stoneway	7.55	5	90.6
2	Concrete Sand	6.1	4	91.5
3	(Barrens filter)	6.06	4	90.9
				91.0
		6.57		
Average				

All tests were performed using a 6" X 419 ~ 30" plexiglass column. The dry profile of the column was S of pea gravel foliwed by 16" of sand or glass and 2" of pea gravel on the bottom.

The relative infiltration rates were measured under saturated conditions with approximately 1" to 6" of static head. The column was allowed to flow for several runs before the tests were conducted.

APPENDIX C

Glass/Sand Filter Diagram, Filter Site # 1

APPENDIX D

Filter # 1 Database

APPENDIX E
Soil Test Results at Filter # 2

AUQA TEST, Inc.
PO Box 950
Maple Valley, WA 98038-0950

Prepared For: Mark Fiska
Ronald, WA

SAMPLE ID: 16”

TEST DATE: 6/9/94

SAND FRACTION	
P(50-2000 MICRONS) =	66.7%
SILT FRACTION	
P(2-50 MICRONS)=	12.7%
CLAY FRACTION	
P(2 MICRONS) =	20.6%
SILT CLAY	
P(2-50 MICRONS)	33.3%

APPENDIX F
Glass Filter System # 2 As-Built

APPENDIX G

Filter #2 Data Base

APPENDIX H

Glossary of Terms

Glossary of Terms

Advanced Treatment Unit Sand Filter, Recirculating gravel filter, or other [roprietary devic which is designed to reduce waste lavels (BOD_5, TSS, O&G) to less than 30 mg.l. Many of these units will consistently produce an effluent quality of less than 10 mg/l.

Aerobic (1) A condition where "free" or dissolved oxygen **is** present. (2) Requiring, or not destroyed by, free oxygen. Generally referring to organisms which use "free" oxygen for respiration.

Anaerobic (1) A conditin where "free" or dissolved oxygen **is not** present. (2) Requiring, or not destroyed by the absence of free oxygen. Generally referring to organisms which do not require oxygen for respiration.

Blackwater Represents flows from bathroom fixtures (sink, toilets and urinals)

BOD_5 Biochemical Oxygen Demand over a five day test period. Thisis presented in mg/L (parts per million – ppm).

DO Dissolved Oxygen, the quantity of oxygen present in solution. A critical factor for aerobic organisms.

Draw down Refers tothe process of pumping a tank down a specific folume during a measured time. This information is then used to calculate the pump discharge rate GPM. Draw downs should be conducted with the tank half full with all of the system components hooked up as they would be for normal operation.

Gallons Per Inch of tank or tanks (from manufacturere or calculated) X
Inches of draw down ÷ Minutes of draw down = GPM

Fecal Coliform An easily detected bacteria which is considered an indicator of the presence of pathogenic organisms.

Greywater Greywater represents the flows from sources other than bathroom fixtures and laundry.

GPD Gallons Per Day

GPM Gallons Per Minute

N/A Not Available or Not Applicable

O & G Oil and Grease measured in mg/L (parts per million). Can include fats, oils, grease, and lotions. Generally requires more time to breakdown than other organic compounds found in residential septic waste.

PH

An expression of the intensity of the alkaline or acidic strength of the water.

Total Nitrogen

Total Nitrogen is comprised of Organic Nitrogen, Ammonia, Nitrate and Nitrite. Septic tank effluent typically has nitrogen in the organic and ammonia forms. This is analyzed with the Total Kjeldahl Nitrogen (TKN) and Ammonia parameters. TKN is a measure of the Organic Nitrogen and Ammonia combined. By subtracting the Ammonia from the TKN the amount of organic Nitrogen can be determined. Once the waste has been treated by a suitable aerobic treatment process, like a sand filter, some or all of the Ammonia is converted to the Nitrate or Nitrite form of nitrogen by nitrifing bacteria.

TSS

Total Suspended Solids measured in mg/L (parts per million). Refers to the residue which is captured on a glass fiber filter disk. Can include both organic and inorganic material.