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Article

Treatment of septic tank discharge using crushed glass filter media

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Abstract : The on-site wastewater treatment system (OWTS) with a sand trench is an economical option for residents in rural areas or the countryside where a centralised sewer system is inaccessible. 2A sand achieves improved filtration, microbial activity and consistent long term performance when compared to gravel or scoria based trench systems. However, it is expensive and only readily available in a few areas across New Zealand. Additionally, it has a reputation for premature blockage when overloaded or compacted. The aim of this study is not only to critically evaluate the performance of Crushed Glass (CG) with respect to 2A sand, but also to investigate different loading rates for CG when treating primary treated effluent from a septic tank. A test rig was designed and constructed to simulate the real environment of the sand column in a discharge control trench. The treatment efficiency of three filters was recorded and compared in this study. Overall, the CG loaded at 25mm/day (CG_{25}) and 50mm/day (CG_{50}) provided an average of 13% and 6% more Total Nitrogen (TN) reduction than the sand filter, respectively. The removal rates for the TN were up to 69.5%. The CG_{50} filter performed similarly at 50mm/day as the 2A sand filter in terms of Total Suspended Solids (TSS) and Biochemical Oxygen Demand $(BOD)_5$ removal of more than 94%. The CG_{25} removal rates for TSS and BOD_5 at the start of the trial (likely due to residual liquid contamination from the bottles when crushed) improved over the sampling period and ultimately achieved similar results of 92% and 91.3% to the filters loaded at 50mm/day. Lifecycle cost analyses and carbon balances were completed for the two media. It highlighted that the current price of CG is only half of 2A sand, yet it produces significantly less CO_2 emissions than 2A sand. A 3-bedroom dwelling could save up to $500 and reduce 200kg of CO_2 released to the environment annually when 2A sand is substituted for CG. Based on the findings of this paper, it is likely that the reduced installation cost, lessened environmental impact and theoretical availability will lead to CG systems becoming more common in New Zealand and abroad.

Keywords: Crushed glass; Carbon emission; Septic discharge; Total Nitrogen

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Introduction

It is estimated that around 270,000 homes in New Zealand rely on onsite wastewater treatment systems (OWTS) to manage their wastewater, with 76 per cent of settlements in Southland using the septic tank as their wastewater disposal system [1]. A conventional septic system works adequately in well-draining soil; however, it does not provide an adequate level of wastewater treatment in areas with sensitive environments, poorly draining soil, or shallow groundwater. The OWTS with a sand trench is an economical option for rural or countryside residents where a centralised sewer system is unavailable [2].

Sand sorted to match the 2A distribution curve to achieve a hydraulic conductivity over 500cm/day, leading to a high hydraulic capacity. In the absence of macropores, parasites are removed by filtration in this sand. Cruz et al. conducted a study on the performance of a full-scale sand filter treating septic tank discharge [3]. 2A sand has been used as a filter medium for a long time and has a good track record. The sand can remove up to 98% of Biochemical Oxygen Demand (BOD_5), 94% of Total Suspended Solids (TSS), 27% of Total Nitrogen (TN) and a log 3 of Faecal Coliform (FC) in the septic tank effluent from a single home. Over the seven-month investigation, the system achieved TSS removal of 87.8%, BOD_5 removal of 92.7%, TN removal of 32%, and log 4 of E. coli reduction. The effluent quality met the legal requirement for discharge, and the sand filter proved to be an effective filter medium. The operation involved scraping and removing the surface of the sand filter to 0.05m [4]. Xi, Mancl and Tuovinen also evaluated dairy effluent treatment with sand filtration in a study. The effluent was dosed to the system daily, ranging from a low rate of 42,000 mg COD/m^2/day to a high rate of 84,000 mg COD/m^2/day Chemical Oxygen Demand (COD)/m^2/day. Over seven months, the system achieved more than 99% BOD_5 reduction and COD reduction of 85%.

In New Zealand, an intermittent single-pass sand filter is promoted as an option for secondary treatment of domestic wastewater. Effluent from a sand filter could be of high quality with typical TSS and BOD_5 concentration of less than 5 mg/L, phosphate of less than 10 mg/L and ammonia of less than 5 mg/L [5].

At present, almost all recycled glass in New Zealand would end up in landfills; 60,000 tons in 2016, with just a fraction of them being used as aggregates, sandblasting media, or landscaping materials, meanwhile, the specialist sand required for sand filter construction has to be quarried from selected rivers dispersed across the country [6].

Recycled glass has been successfully employed as a filter medium in several studies regarding the treatment of potable water [7]. Rutledge and Gagnon compared the performance of crushed recycled glass to silica sand used in dual media anthracite-sand filters for water filtration [8]. The research showed that crushed glass (CG) media filter initially produced slightly lower removal efficiency than sand media filter in terms of particle removal efficiency; however, after six months in operation, it was able to achieve a higher particle removal of 50-70 particles/mL compared to sand filter with 25-50 particles/mL. The ripening period of the sand filter was less than 10 minutes, which was much shorter than that of the CG filter with 15 to 20 minutes. It was suggested that the angularity of glass media dictates the settling time of the filter; the higher the angularity, the lower the filter settling time. Evans et al. investigated the filtration performance of recycled glass as a filter media with respect to sand for the treatment of municipal potable water [9]. The single media filter was 90 cm deep and both media had a similar effective size of roughly 0.9 mm. The author found that glass and sand have similar treatment performance in terms of turbidity, particle counts and metals content.

Recycled glass has also been used as a filter medium in several trials for secondary treatment of wastewater. Secondary and tertiary treatment

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of sewage using CG have been studied in the US and and the UK with periodic backwashes for application in wastewater treatment plants [10]. A pilot-scale and a field scale application of recycled glass have been studied for wetland wastewater treatment [11] [12]. Laboratory-scaled filter column has been used to compare the treatment performance of CG versus sand and soil [13]. From these trials it has been found that CG performed equally well as sand, especially in TSS, BOD_5, TN and FC removal. Published research supported by Clean Washington Center investigated the use of CG as a filter medium for intermittent sand filter treating a septic tank discharge from an individual home [14]. The trial was set up and monitored over two years to measure the filtration performance of CG and C-33 sand (ASTM C-33 guideline values are similar to the 2A rating of the MESO diagram) under the same loading condition. It was concluded that CG could be used as an alternative to C-33/2A sand for the filter system. While C-33 sand out-performed CG by a slight margin in terms of BOD_5, TSS, O&G, and FC reductions, CG performed slightly better than C-33 sand in terms of nitrate reduction [14]. Elliot evaluated the performance of CG as a filter medium for a 15,000 gallon-per-day recirculating intermittent sand filter serving approximately 50 residential homes [15]. The performance of the filter was monitored closely over sixteen weeks and filter influent and effluent was tested weekly for TSS, BOD_5, and ammonia. Over the testing period, the filter achieved 98% removal of TSS, nearly 96% removal of BOD_5 and 94% reduction of ammonia.

Dryden Aqua found that glass media dealt very well with wastewater with a high concentration of nutrients and bacteria and removed 90% to 95% of solids and chemicals in wastewater [16]. Horan and Lowe also found that medium-size glass and sand had similar TSS removal rates [17]. For solids concentration less than 70 mg/L, glass achieved up to 75% of TSS removal. Glass media also showed better flow handling capacity, therefore was able to cope with an 8% to 10% increase in the hydraulic loading following the backwash cycle. Hu and Gagnon conducted a pilot-scale studying the effect of hydraulic loading rates, dosing frequency, recycled ratio and media characteristics on the performance of recirculating biofilters treating domestic wastewater [18]. Different media such as sand, glass, textile and peat were compared and it again found that glass performed equivalent to the sand media. The study also found that higher dosing frequency at low recirculation ratios improved BOD_5 removal significantly. Gill et al., from Ireland conducted a trial that compared the treatment efficiency of sand and glass as filter media for polishing filters treating on-site wastewater from a single house over two years [19]. The results showed that on average the glass filter performed equivalent to the sand filter for the majority of monitored parameters (BOD_5, COD and FC). However, the glass filter performed much better than the sand filter in terms of total nitrogen reduction, at 1.5 times. In contrast, phosphorous removal was higher in the sand filter than the glass filter, at 51% and 40% reduction.

Additionally, the use of CG in filtration experiments was also highlighted in a few studies. Piccirillo examined the use of pulverised waste recycled glass as filter media for slow sand filters [20]. The glass was pulverised using a mill pulveriser, and the product met the requirements of ASTM C-33 (comparable to 2A sand). The trial consisted of three pilot sand filters with recycled glass as a filter medium and one sand filter with silica sand as a filter medium. It was operated for eight months and at the end of the period, the performance of the glass filter and sand filter were compared. Overall, the sand filter with glass media performed just as well as the sand filter with silica sand, achieving 56% to 96% of turbidity removal; a log 4 to complete coliform removal; a log 5 of giardia cysts removal and a log 4 of cryptosporidium cysts removal. Soyer et al. evaluated the performance of recycled glass and silica sand in dual media filters treating raw water sources with different turbidities [21]. The filters contain either 62.5 cm of sand or glass and 41.5 cm of anthracite coal. The filter media had similar effective size and uniformity, around 0.7 and 1.3, respectively. The author concluded that effluent quality was very close for both media in terms of turbidity and particle counts and the glass-anthracite filter created smaller clean-bed head loss and clogging head than the sand-anthracite filter. Gill et al. conducted a study investigating recycled glass as a substitute media to sand in a sand trench or as a soil conditioner in the mound system [22]. The study involved testing and monitoring two filters (sand and recycled glass) dosed with different hydraulic loading rates, ranging from 42 to 85 $L/m^2/d$. The report concluded that both filters achieved similar outcomes, attaining 72-83% BOD_5 removal, 16-26% TN removal, and 3.7-4 log FC removal. However, it also highlighted that smaller doses of effluent at higher frequencies could produce a better waste constituent reduction. In terms of using recycled glass as an addition to the clay subsoil, the report showed significant improvement in the rate and uniformity of filtration.

There was little-to-no information about the long-term performance of CG as filter media for OWTS. However, it was shown in previous research that CG media could potentially achieve a 91% reduction in TSS, 96% reduction in BOD_5, 29% reduction in TN, and a log-3 of FC when used for small-sized wastewater treatment units [14].

Previous researchers compared the efficiency of crushed glass versus other filter media for different contaminants. The impact of daily discharge rate on crushed glass has not been investigated in previous research studies. Evaluation of performance between CG and 2A sand from local resources as filtration media in New Zealand is investigated in this research. This research more importantly compares the effect of different hydraulic loadings on the performance of CG filters, which has not been investigated in any published studies. Additionally, case studies have also been conducted to compare the cost and the CO_2 emissions of the two media, which provides valuable information for any future studies into CG.

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Methodology

The test rig

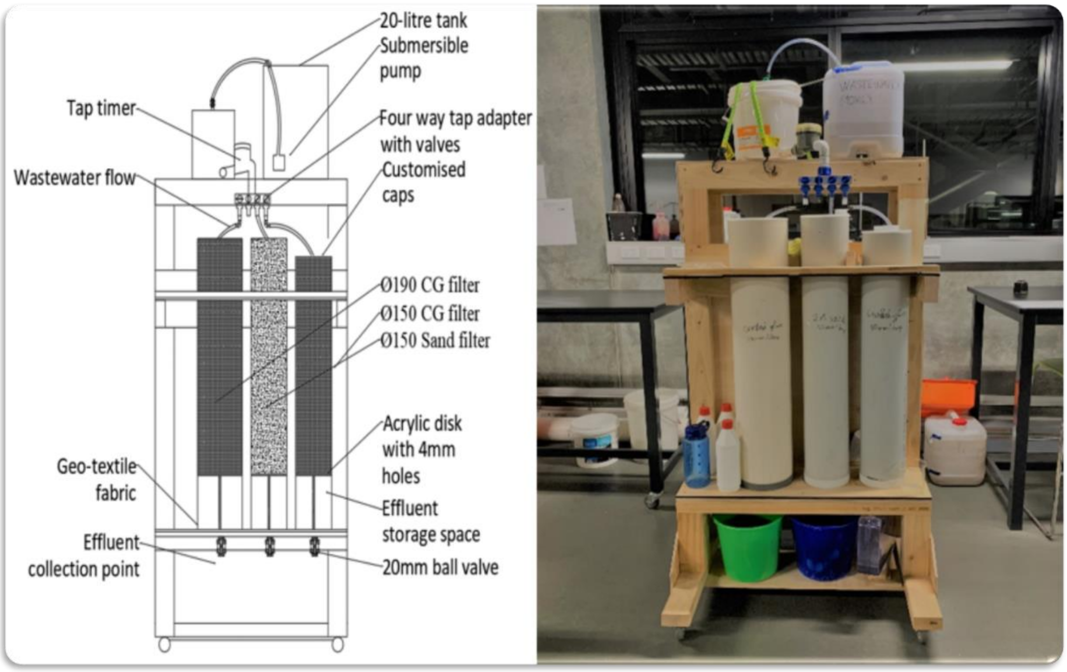

Figure 1: The schematic and set-up test rig for different filter media and loading rates

The test rig simulated a discharge control sand trench through a sand column treating septic tank discharge from a single house in Wainui, Akaroa. The septic tank discharge (filter influent) was collected on a weekly basis and stored on the 20-litre container as shown in Figure 1. The effluent was pumped to a smaller container by a program-controlled submersible pump from the main tank and was distributed to one 2A sand filter and two CG filters through a series of valves and tubes. The 2A sand filter in the middle and the CG filter on the right-hand side was designed with a hydraulic loading of 50 L/m²/day (equivalent to 50 mm/day) and the CG filter on the left-hand side was designed with a hydraulic loading of 25 L/m²/day. The filters consist of a layer of fabric mesh to protect the surface of the filter from hydraulic erosion, an effective media depth of 600mm and a layer of Bidim 19 geotextile to stop the media from slipping through the filters. Sampling buckets were placed directly under the filters to collect effluent for analysis.

The sand media used in this study was 2A sand or concrete sand, obtained from Fulton Hogan Quarries Canterbury. Figure 2 showed that the material had a uniformity coefficient (Uc=D60/D10) of 3.79 and a mean grain size of 0.35 mm. Therefore, when plotted on the MESO diagram, the sand fell into the lower end of the 2A range.

The glass media used in this study was CG, obtained from Fulton Hogan Quarries Canterbury. Figure 2 showed that the material had a uniformity coefficient (Uc=D60/D10) of 6.91 and a mean grain size of 2.20 mm. Therefore, when plotted on the MESO diagram, the sand fell into the higher end of the 2A range. Both samples however were both met the 2A grading.

A 20 litre tank with a submersible pump is used to pump wastewater the second chamber. Wastewater then flows by gravity at a certain time adjusted on the tap timer to the four way adapter. Wastewater is then distributed at the adjusted rates using the valves.

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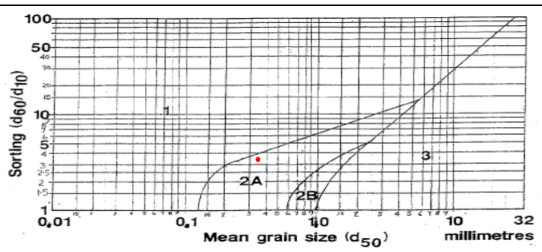
2A sand

SIEVE SIZE (mm)	% PASSING SIEVE	Diameter Measurements (Linear interpolation)
9.5	100	
4.75	100	Sorting CU = 3.79
2.36	79	
1.18	70	
0.600	63	
0.300	46	d50 = 0.35mm
0.150	11	
0.075	1	



CG (2A)

SIEVE SIZE (mm)	% PASSING SIEVE	Diameter Measurements (Linear interpolation)
13.2	100	
9.5	100	
6.7	97	
4.75	89	Sorting CU = 6.91
2.36	55	
1.18	30	D50 = 2.20mm
0.600	16	
0.300	8	
0.150	4	
0.075	1	

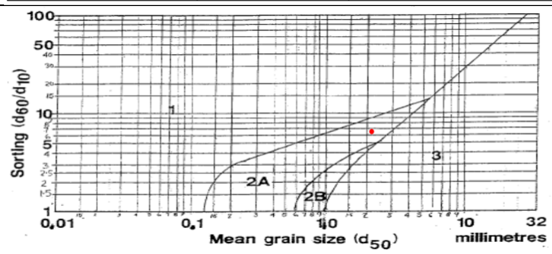


Figure 2: Filter sand sieve analysis for 2A sand and crushed glass (Source: Adapted from Fulton Hogan)

Sampling and analysis

The overall performance of filter media has been compared in six different wastewater parameters (TSS, BOD_5, TN, E.coli, pH and Temp). Sampling was carried out weekly throughout the study; each sampling volume was calculated based on the hydraulic loading rate of three filters and the sampling frequency. All filter influent and effluent samples were analysed for wastewater parameters at the same time.

Hydraulic loads

The hydraulic loads for the 2A sand filter and the CG_{50} filter were 50 mm/m^2/d and the hydraulic load for the CG_{25} filter was 25 mm/m^2/d. The filters were dosed three times per day throughout the trial with a rest period of eight hours between pumping cycles. The average temperature across the whole trial was 19°C, with a low of 17°C and a high of 22°C. The influent pH level ranged from 6 to 9 across the trial. Likely influenced by the COVID-19 lockdown and increased occupancies over three weeks during testing.

Results and Discussions

Septic tank discharge (influent)

The waste strength data for septic tank discharge (influent) are shown in Table 1. The average waste concentration of septic tank discharge throughout the study was 56.1 mg/L for TSS, 107 mg/L for BOD_5, 43.8 mg/L for TN, 7.4 for pH and 19.8 °C for temperature. When comparing septic tank effluent with the typical waste strength values for primary treated wastewater as indicated in Table 1, the result was well within the expected range.

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Table 1: Typical domestic effluent quality before and after sand filter

Treatment system	Typical concentration			
	g/m³			cfu/100 mL
	TSS	BOD_5	TN	FC
Septic tank with effluent filter [23]	20-50	100-140	50-90	10^5-10^{10}
Septic tank discharge (this trial)	**56.1**	**107**	**43.8**	**NI**
Septic tank with single-pass sand filter [23]	0-5	0-5	<30	$4 \times 10^2 - 10^4$
Septic tank with 2A sand filter (this trial)	**3.6**	**5.5**	**15.2**	**NI**

Water quality monitoring

The removal of TSS and BOD_5 in wastewater is accomplished by both physical and biological mechanisms. The filter media acts as a strainer to retain solids from wastewater in the gaps between the media particles and the naturally occurring microbes inside the filter will consume contaminants in the wastewater to grow and eventually form a microbial biomat. A healthy biomat is capable of removing bacteria and viruses. A working filter with abundant oxygen and food supply (contaminants in wastewater) should exhibit a consistent reduction of TSS and BOD_5 once established (after week 5).

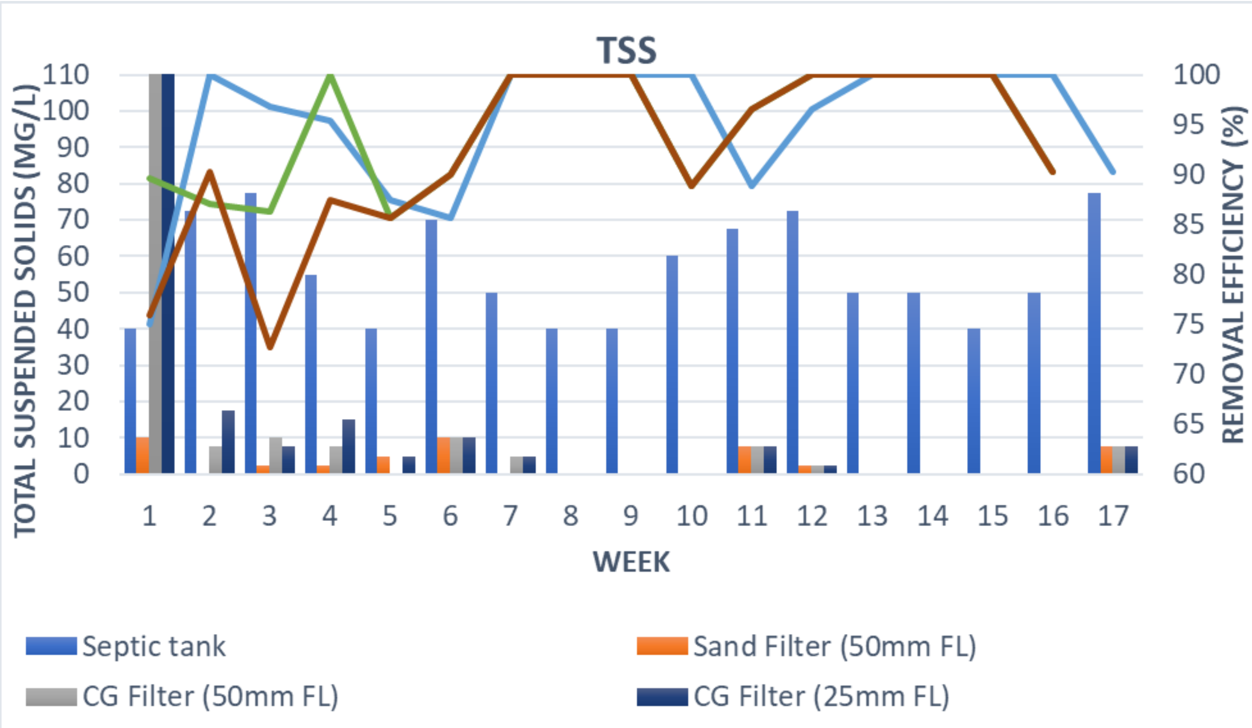

Figure 3: TSS concentration and removal rates of filter influent and effluent over seventeen weeks

The concentration and removal efficiency of filter influent and effluent were recorded over seventeen weeks, as shown in Figure 3. The CG_{50} removal rate, CG_{25} removal rate and sand filter removal rate is shown by green, red and blue lines, respectively. as a filter material did not go through a washing and drying process during production like 2A sand, therefore resulting in the excessively high concentration of TSS and BOD_5 during the first week of trial. There were a few special occasions that resulted in the abnormally high concentration of TSS and BOD_5.

Week 11 to week 13 of the trial fell into the lockdown period in Christchurch and Week 17 fell into the long weekend of Labour Day. Leaving aside those mentioned occasions, the sand filter showed a good and consistent performance in TSS reduction over the first six weeks and eventually achieved <1 mg/L of TSS over most of the period. The CG_{50} filter showed a slightly fluctuating trend over the first seven-week period then achieved a 100% removal rate for most of the weeks after. The CG_{25} filter showed the lowest removal rate in the three over the first seven-week period. In general, each filter seemed to have a different removal efficiency at the start, but all achieved their maximum removal rates after week eight which were very similar.

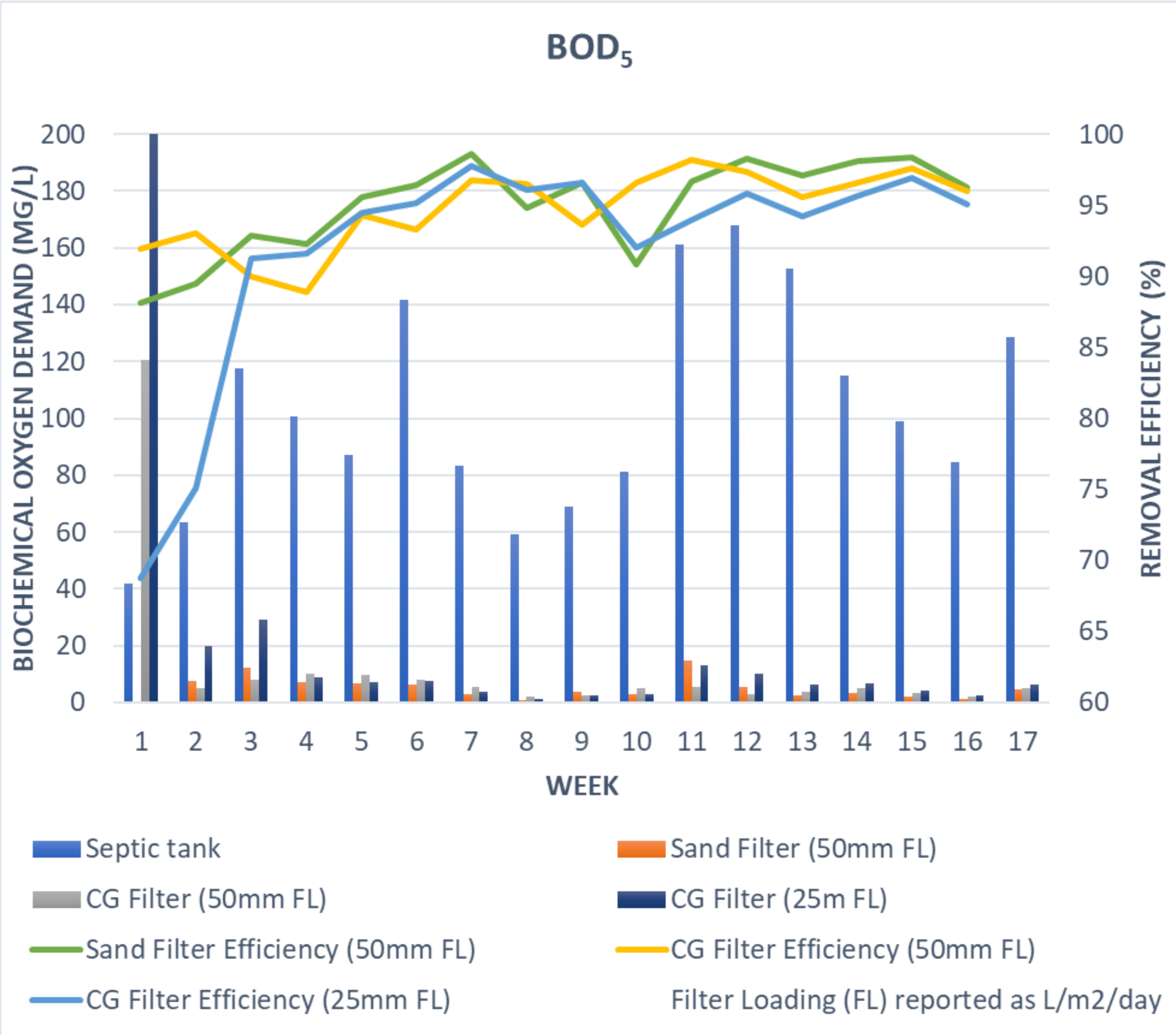

Figure 4: BOD_5 concentration and removal rates of filter influent and effluent over seventeen weeks

Figure 4 shows the concentration and removal rates of BOD_5 in septic tank discharge and three filter effluents. The reason for the high concentration of BOD_5 during the 1st, 11th to 13th and 17th week is as mentioned in Section 3.1.1. The sand filter showed a good and consistent performance with a gradual increase in the BOD_5 removal rate over the seventeen weeks. From week three to week 7 and week 12 to week 15, the sand filter achieved a 95.9% removal which coincided with the times when the filter achieved a 100% removal rate TSS. The CG_{50} filter showed

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a slightly fluctuating curve at the start of the trial, from week one to week five, but gained a steady increase in the BOD_5 removal rate afterwards, averaging nearly 95.1% reduction from week 10 to week 15. The CG_{25} filter showed lower BOD_5 removal rates in weeks 2, 3 and 4, but performed better from week 5 forward to the end of the period. In general, each filter seemed to have a different removal efficiency at the start, but all of them got to their maximum removal rates after week 6 in excess of 95%.

Table 2: TN removal rates from the influent to the effluent of the unit

Source	FL	TN	
		23rd Oct	30th Oct
Septic tank		36.1	51.5
2A sand filter	50	14.4 **(60.1%)**	22.3 **(56.7%)**
CG filter	50	11 **(69.5%)**	19.4 **(62.3%)**
CG filter	25	11.2 **(69%)**	20.3 **(60.6%)**

(%) – Percent Reduction
TN is reported as mg/L
Filter loading (FL) reported as L/m²/day

The reduction of TN relies on the conversion of Ammonia to Nitrite and from Nitrite to Nitrate through natural processes such as denitrifying bacteria and other mechanisms. The filter influent and effluent were tested for TN on weeks 16th and 17th of the trial, all filters achieved removal rates within the 55% to 70% range as shown in Table 2. The two CG filters had similar removal rates and both were better than the sand filter. Week 2 of the TN test saw the TN concentration increase by 30%, the reason for that is because week 17 of the trial fell onto the long weekend of Labour Day. Additional nitrate reduction testing is required and is proposed to be completed in 2022.

Table 3: E.coli removal rates from the influent to the effluent of the unit

Source	FL	E.coli	
		11th Nov (Hill Labs)	25th Nov (Hill Labs)
Septic tank		16,000	160,000
2A sand filter	50	2 **(log3.9)**	2 **(log4.9)**
CG filter	50	2 **(log3.9)**	2 **(log4.9)**
CG filter	25	2 **(log3.9)**	2 **(log4.9)**

(log) – Log Reduction
E.coli are reported as MPN

The testing of filter effluent and influent for E.coli was advised to be conducted within 24 hours of sampling, however, it was impossible due to the long distance between the septic tank discharge source and the filters as well as the time it takes for the filter to produce adequate amount

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of effluent for testing [24]. Therefore, the information demonstrated in Table 3 is indicative only and should not be relied on for any purpose. For the first E.coli test, the septic tank sample was stored under ambient temperature and all sample was collected at the same time for testing, the concentration of E.coli from the septic tank on the first testing was 16,000 MPN, which was significantly lower than what is expected of a septic tank. It demonstrates that E.coli deteriorates at a significant rate when not in the septic tank environment. For the second test, the septic tank sample was immediately preserved at 4° until the sample submission date. The E.coli concentration was 160,000 MPN, which matched the typical primary treated effluent from a septic tank.

Table 4 shows the laboratory results of filter influent and effluent for the monitored parameters; it also shows the respective removal rate for each filter.

Table 4: Average waste strength and removal rates for filter influent and effluent

Source	Filter loading	TSS	BOD_5	TN	pH	Temp.
Septic tank		56.1	107	43.8	7.4	19.8
2A sand filter	50	2.2 **(96.5%)**	5.6 **(94.7%)**	18.4 **(58%)**	6.9	20.2
CG filter	50	3.6 **(94.6%)**	5.5 **(94.5%)**	15.2 **(65.3%)**	7.2	20.3
CG filter	25	5 **(92%)**	8.9 **(91.3%)**	15.8 **(63.9%)**	7.5	20.4

(%) – Percent Reduction
TSS and BOD_5 are reported as mg/L   Filter loading reported as L/m²/day
Temp reported as °C

The performance of each filter media

Unlike raw CG media with a high concentration of contaminants when sourced, 2A sand was quite clean when sourced. The 2A sand filter , therefore, worked well from the start, with an average effluent concentration for TSS, BOD_5 and TN of 3.6 mg/L, 5.5 mg/L and 15.2 mg/L, which correlates quite well with the typical concentration of septic tank with sand filter as shown in Table 1. In addition, the average pH and temperature were 6.9 and 20.2, which are also within the normal range for sand filter effluent.

Recycled glass was crushed from a mix of clean and dirty jars and bottles, without being washed, resulting in extremely high concentration and negative removal rates for all waste strength parameters in the first week. Through continued effluent loading, the second week of the trial measured contaminate washed out, and the resultant performance trended to match the 2A sand performance.

The CG_{50} filter's removal efficiency was 94.6% for TSS reduction and 94.5% for BOD_5 reduction, respectively, which is similar to the 95% removal rate of the 2A sand filter.

The CG_{25} filter averaged 5 mg/L in TSS and 8.9 mg/L in BOD_5, equating 89.1% and 89.6%, respectively. The establishment of the biofilm

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was at a reduced rate due to the reduced loading rate, however once established, the CG_{25} achieved similar removal rates to the sand filter and the CG_{50} filter after two months. Nevertheless, it was an interesting phenomenon as it shows the effect of hydraulic loading on the biomat establishment and performance of the filter.

Overall, the performance of both CG filters aligns with the literature review. The current information available on the performance of CG as a filter media shows that it could achieve a 91% reduction in TSS and 96% reduction in BOD_5, and results from this trial show that CG averaged 94.6% for TSS reduction and 94.5% for BOD_5 reduction. CG from this trial achieved a substantial 65.9% of TN removal, which is far more effective than the literature review. However, industry professionals have confirmed that a 60% TN reduction could occur under optimum conditions, therefore the 65.9% reduction of TN is acceptable.

Refer to Table 5 for a detailed breakdown.

Table 5: Removal rates comparison between current literature and this project

Treatment system	Typical concentration			
	%			log
	TSS	BOD_5	TN	FC
Septic tank with CG filter [14]	91	96	29	3
Septic tank with CG filter (this trial)	**94.6**	**94.5**	**65.9**	**NI**

The average pH levels throughout the study for the CG_{50} filter and the CG_{25} filter were 7.2 and 7.5, which were very close to the condition experienced in the septic tank and the sand filter. These pH levels ensured an effective environment for the beneficial bacterial and organism to break down the organic and chemical compositions of the filter influent; it also created an ideal condition for the nitrification process to occur.

CO_2 and Cost analysis

CO_2 emissions from material production

According to the process flow for the production of two media in Figure 5, the main contributing factor to CO_2 emissions comes from fuel consumption of machinery and transportation. Therefore, the total fuel consumption was calculated based on engine operating times and fuel consumption. The CO_2 emissions were calculated by multiplying the total fuel consumption by 2.62 kg, which is the typical CO_2 produced by burning a litre of diesel. Emissions related to the installation of the sand trench and finishing of the discharge field are assumed equal due to the only change being the media.

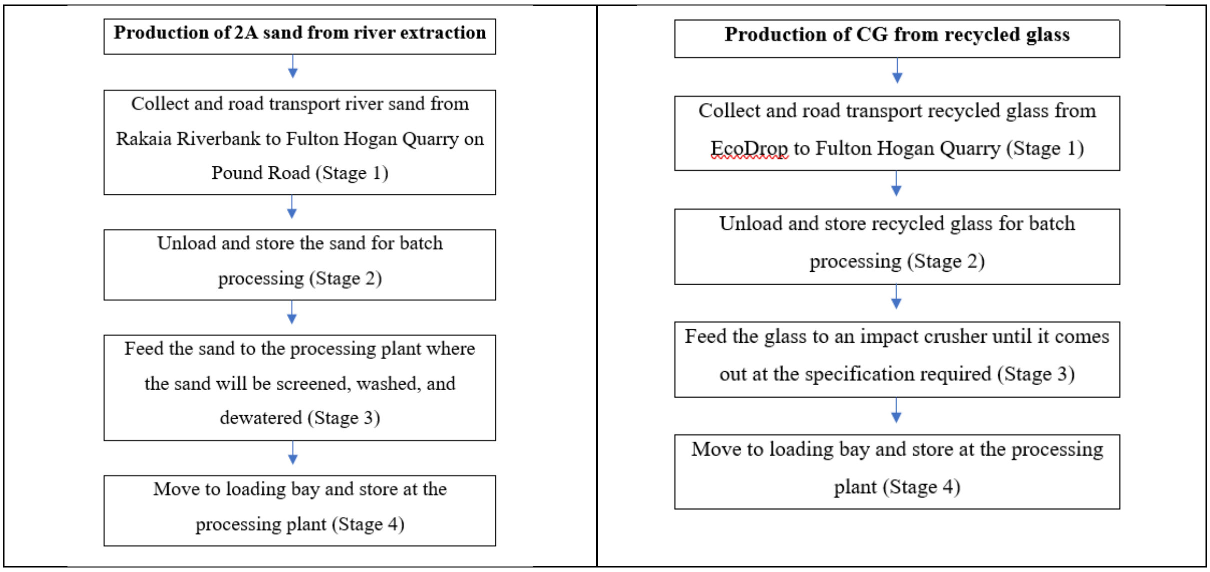

Figure 5: Process flow for 2A sand and CG production (Source: Adapted from Fulton Hogan)

The case study shows that while it only takes 37.50 litres of diesel to produce 20 tons of CG, it takes up to 115 litres of diesel to produce the same amount of 2A sand, which is an equivalent of 98 kg of CO_2 and 300 kg of CO_2 respectively [25]. The reason for the significant difference in CO_2 is due to the longer distance of travelling to collect raw sand from the Rakaia River. Recycled glass is typically collected from the curbside and processed nearby, therefore consuming less fuel overall. The washing of the 2A sand was not included, as it is recommended that all CG undergoes the same process to prevent high concentration effluent in the first month of discharge to ground.

Cost analysis

The case study involved comparing the difference in media cost for the two media. The cost of the media was calculated by multiplying the cost per ton by the volume of 2A sand or CG needed to fill in a discharge control trench serving a three-bedroom home and a six-bedroom home. Using CG as a filter medium for a discharge control trench is more economical than 2A sand. By changing the filter material from 2A sand to CG, the contractor could potentially save as much as $500 for a three-bedroom and $1000 for a six-bedroom house. Refer to Table 6 for a complete breakdown.

Table 6: Cost comparison for two scenarios

Trench media	Price ($/m^3)	Volume (m^3)	Cost ($/system)
3-bedroom dwelling			
2A sand	87.11	10.8	940.79
CG (2A)	39.91	10.8	431.03
6-bedroom dwelling			
2A sand	87.11	19.4	1689.93
CG (2A)	39.91	19.4	774.25

A case study of 100 typical houses shows that investing in a mobile glass crusher unit only takes 2.4 years for investors to achieve payback, assuming the unit produces 1700 tons of CG each year. Having a mobile glass crushing station on-site would also reduce the CG price from $25.75

to $14.50. In addition to the cost-benefit, using indigenous recycled glass would lower the CO_2 emissions significantly, and pave a sustainable pathway for the future.

Conclusions

Based on data from the test trial and comparison with the baseline, it is now proven that CG could be a suitable substitute for 2A sand in standard sand trench design with loading rates up to 50mm/day. Overall, when having the same hydraulic loading, CG performed similarly to 2A sand in terms of TSS, BOD_5 reduction. CG achieved a higher TN reduction of 65.3% compare with 58% for the 2A sand. The TSS and BOD_5 removal rates were all near 95% for both CG and the 2A sand. Between the two CG filters, the hydraulic loading does seem to have an effect on the removal rate of the filter at the start, but after eight weeks, both filters achieved similar removal rates in all tested parameters. The filter media also showed its ability to remove E.coli. The same log removal of 4.9 is achieved for all media and loading rates.

The price of CG is currently half of 2A sand, yet it produces significantly less CO_2 emissions than 2A sand, CG when used as filter media for a 3-bedroom dwelling could save up to $500 and reduce 200 kg of CO_2 released to the environment. The case study on the capital and return period for a mobile glass crusher unit also shows that investing in a mobile glass crushing unit is beneficial. It will only take 2.4 years for the operation to return $134,000 capital to the investors and after that, the price of CG could be reduced significantly from $25.75 to $14.50. Using crushed glass as a filter medium could lower the material cost for a trench filter and potentially create a viable market for the abundant recycled glass stockpile in New Zealand.

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