01 Introduction

This study is to look at greywater produced at domestic level and to look at natural sustainable filtration methods that could be used to help reduce water waste by using reclaimed water where possible in a home.

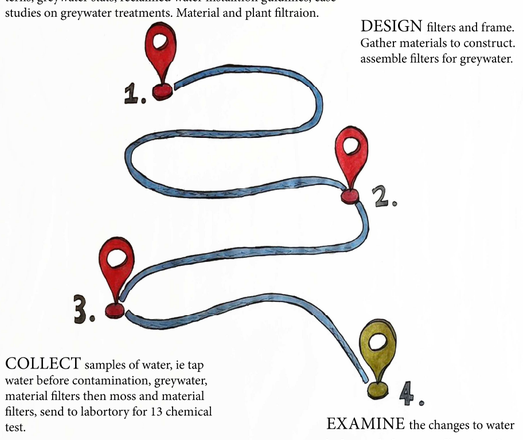
02 Aims

The Aim is to determine whats in greywater and how harmful is it to humans and the environment. Test how difficult it is to treat using simple, sustainable and natural raw materials. What standards can be achieved through natural filtration mediums. Compare the quality of greywater before and after filtration and tested to EU Potable water standards. To further develop technology to reduce water waste in homes. If the water can be reused? Where? Could this technology be applied in architecture design?

03 Objectives

RESEARCH EU potable water standards, EPA stats on water levels and natural water quality in irealnd, water uasage patterns, greywater stats, reclaimed water installtion guidlines, case studies on greywater treatments. Material and plant filtraion.

DESIGN filters and frame. Gather materials to construct. assemble filters for greywater.



COLLECT samples of water, ie tap water before contamination, greywater, material filters then moss and material filters, send to labortory for 13 chemical test.

EXAMINE the changes to water before and after water filtration. Categories the reuses of the water, energy reduction by reusing greywater.

04 Motivation

As an Architectural Technology Student, the role is to attempt to identify and provide solutions for problems in Residential, Commercial, and the Industrial Sector. Not only the performance of a building is important but how a buildings existence impacts the environment. It is well known that water resources availability varies across the country. Under growing pressure from population increase, increasing demand and climate change. With an interest in water quality and a background in water drilling as a family business. I know the importance in the need for clean water and sanitation. It is a natural resource that needs to be respected. There's a natural cycle of water and by human impact it can have a knock-on effect which can lead to contamination either in ground water and flowing waters.

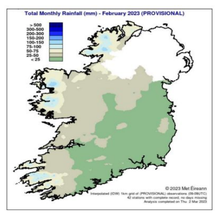
05 Scope

The scope of this study is to look at how water is used in Ireland in a domestic setting. The chemical contaminates in greywater. To attempt to filter greywater to the best level possible, for reuse within a home which is not potable water. The focus is to look at the water usage in a typical domestic home globally and in Ireland.

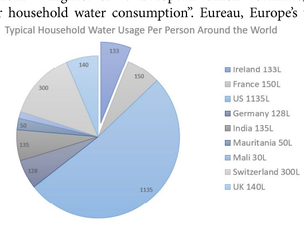
06 Literature Review

"By 2025, nearly 1.8 billion people will live in areas with absolute water scarcity, and two thirds of the world population could face water-stressed conditions." United Nations Press Release March 2016.

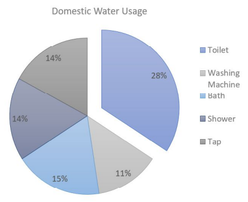
In the EPA Monthly Hydrology Bulletin Report, February was reported the driest month in years. Rainfall averages were below the normal range Across the country. In County Wexford it was its driest February since 1986. However , March rainfall was Above average around the country. Reports in Donegal Had seen precipitation exceeding 227% and Dublin Airport reported its wettest march since 1947.



"Ireland is ranked 10th highest of 25 European Union countries, excluding Latvia and Lithuania, for household water consumption". Eureau, Europe's water in figures.

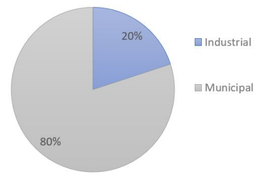


"In November 2021, European Commission referred Ireland to the Court of justice of the European Union for failure to comply with the requirements of Drinking Water Directive." "This applies to water management suppling towns and cities but also the source of water ie; lakes, rivers and reservoirs."



It is estimate that 70% of clean potable water is output as greywater. Based on water usage patterns in a typical household in Ireland, at least 370 Liters of greywater that could be recycled, is mixed in sewage everyday.

The main source of serious pollution in Ireland according to the EPA is:



Water quality describes the condition of the water and its characteristics. **Water standards** categories the condition of the water into levels that are for its use and consumption. The **EU** sets out guidance on the Maximum Admissible Concentrations in Waters for Potable Use.

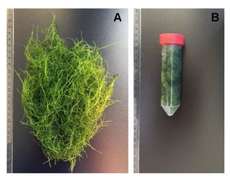
Plant Filtration

Location:
Archerstown County Westmeath

Moss Facts

- Mosses are non-flowering plants which produce spores and have stems and leaves, but don't have true roots.
- Classified as Bryophytes
- Mosses grow in many different environments, can adapt to inhabitable areas.
- Mosses function like sponges, using their capillary spaces to hang on to water.

Phytoremediation



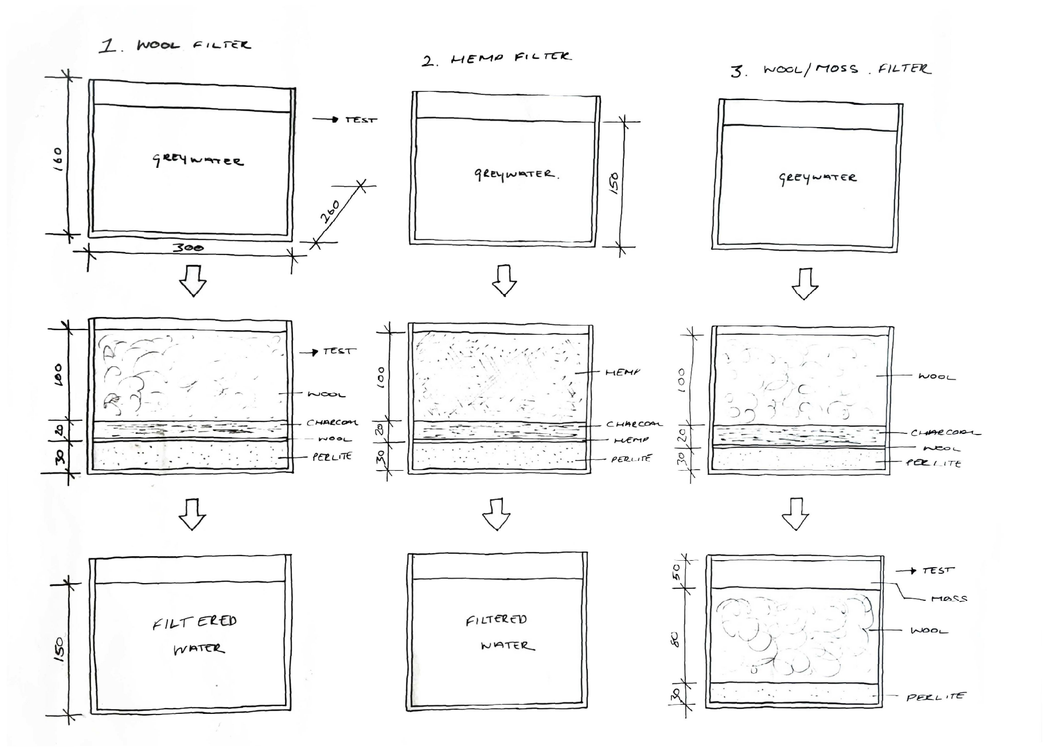
Aquatic moss submerged with greywater in vile.

Testing how non Aquatic ie; Feather Moss survives being submerged in dishwasher water over a period of time.

Phytoremediation is when plants uptake contaminants such as metals, pesticides and chemicals. Moss, with gametophyte characteristics, can act as live filtering material.

Material Filtration

Filter Design

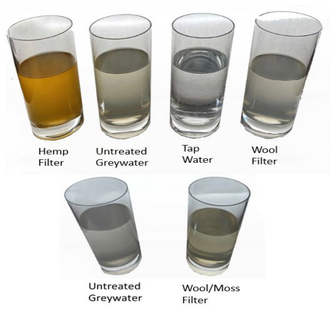


Researching filtration systems for greywater. The case study on green roofs in the Greek Islands, has shown success in the treatment of light greywater. This inspired further research into plant and natural material filtration which led to the prototype tested in this study.

The section shows, the layout of the filters, the thickness of the materials and at what stage testing is carried out. The water is gravity fed to the bottom of the container which forces the water to filter through the mediums , then overflow into the next container, where the water is collected. The filters are supported on a three tier frame which elevates the containers to improve the water flow. The filters consisted of wool, hemp, perlite, charcoal, and native Irish feather moss (Eurhynchium striatum).

For the moss layer it could not be submerged in water (previous trial over a period of weeks submerged in greywater showed the moss would not survive) so as a prop for the moss to be at the waterline, a layer of perlite and wool was added.

Previously testing the wool filter, there was a problem when the water was filtering through the perlite and wool, the materials were dry and light, so it began to float rather than soak the water. These brackets prevent that and allow the water to penetrate through the material and keep in place.



The hemp filter did not improve the water quality from a visual point and the odor of the water was intensified. Sample strips indicated a rise in nitrogen. Therefore, a decision was made to not test the hemp filter further. However, the wool did show improvements visually and therefore laboratory testing were carried out.

Preliminary Testing Only

- A data sheet was made on Excel.
- 3 test strips were carried out for each sample of water, the results were aggregated to an overall average.

Results can vary, overall if levels in any parameters were very high it would indicate so. For accuracy the laboratory results are to be analyzed, with conclusion.

Results							
Parameter	Hemp 1A	Untreated Greywater	Tap Water	Treated Tap Water	Wool	Wool + Moss	Limits
Total Alkalinity	>120	180	180	0	180	<40	120
PH	>8.4	8.4	8.4	6.2	8.4	>6.2	7.2-7.8
Hardness	250	250	500	250	250	50	250-500mg/l
Cyanuric Acid	30-50	30-50	30-50	<30	30-50	0	0-50mg/l
Total Chlorine	0	0	0	0	0	0	0mg/l
Free Chlorine	0	0	0	0	0	0	0-1mg/l
Free Bromine	0	0	0	0	0	0	0-1mg/l
Nitrate	0	0	0	0	0	0	0-10mg/l
Nitrite	0	1	0	0	0	0	0-1mg/l
Iron	0	0	0	0	0	0	0mg/l
Chromium	0	0	0	0	0	0	0-2mg/l
Lead	0	0	0	0	0	0	0mg/l
Copper	0	0	0	0	0	0	0mg/l
Mercury	0	0	0	0	0	0	0mg/l
Fluoride	0	0	0	0	0	0	0mg/l
Carbonate Root	80	80	80	20	80	20	0-20mg/l

08 Testing

Testing will be carried under laboratory conditions, by Oldcastle Laboratories, certified in testing potable water to EU Standards.

Testing As Follows:

- Stage 1, the testing of tap water before contamination.
- Stage 2, the testing of untreated greywater collected from various sources such as (kitchen sink, bathroom sink, shower, bath, washing machine and dishwasher).
- Stage 3, the testing of the materials filters (wool, charcoal, and perlite).
- Stage 4, the testing with moss added as a filtration layer.

List of 13 parameters sample are tested to. Samples are tested against the highest water quality (potable drinking water).

	Parameter	Total Limit	Test Method
	Chemicals		
1	Ammonia	0,3mg/l	TM2118
2	Calcium	200mg/l	TM2129**
3	Maganesium	50mg/l	TM2129**
4	Nitrite (NO2)	0.3mg/l	TM2118**
5	Nitrate (NO3)	11.3mg/l	TM2216
6	Iron	200µg/l	TM2114**
7	Manganese	0,05mg/l	TM2121**
8	Conductivity	2500µS/cm (Siemens per centimetre) @20Deg	TM2132**
9	Total Hardness	N/A	TM2129**
10	Apperance	N/A	TM2219**
11	Colour	20 Unit PtCo	TM2126**
12	Odour	N/A	TM2217**
13	PH	No Less PH 6.5 , No High PH 9.5 @ 20Deg	TM2128**

Can greywater be reused in a home?

Greywater

Light

Bathroom
Contains Shampoos, body care products, hair, lint

Washbasin
Contains soap, toothpaste, body care products, shaving waste and hair

Dark

Laundry
Contains Soap, Bleach, oils, Paints, Solvents, and Non Biodegradables.

Kitchen Sinks
Contains Food Residue, High amounts of oil and fats, dishwasher detergent.

Did you Know?
The public water service in Ireland provide drinking water to over 80% of the population, delivering over 1,600 million liters of water each day.

What's in Greywater?

Greywater is what once was clear drinking quality water, is introduced with detergents, chemicals, metals, bacteria, lint from fabrics and other particles.

Why is Greywater harmful?

Chemicals when released into the environment ie; Septic tanks (30% of Ireland's Population) and land disposal, which Ireland disposes of 80% of its waste sludge via agriculture. Plus from general contamination as shown in chart from EPA.

This can cause:

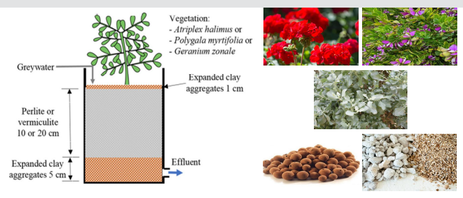
- Spikes in harsh chemicals, phosphorous which cause algae blooms,
- High levels of nitrates , which leads to fish kills, damaging ecology and vegetation.

(Ireland is about 45% compliant with sewage treatment in line with EU legislation).

Waterborne diseases is when bacteria enters water. Bacteria living in harsh environments such as heavily chemical contaminated water can evolve and become antibiotic resistant bacteria known as ARB making illness difficult to treat.

"It's absurd that in the 21st century people still keep flushing their toilets with precious water, as it is becoming scarcer every day." Arthur Valkieser
Founder of Hydraloop.

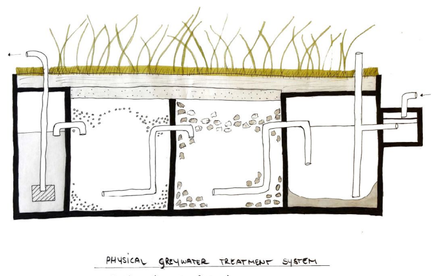
Case Studies



A study on green roofs in the Greek Islands:

- Plants such as, Geranium, Mediterranean Salt Bush, Myrtle-leaf milkwort.
- Substrate of Perlite, Vermiculite and Clay.

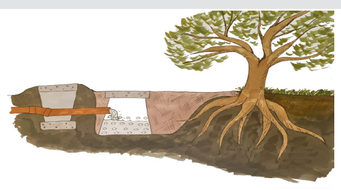
Results suggest that intensive green roofs filled with 20 cm of vermiculite and 5 cm of LECA (baked clay) could treat efficiently light greywater.



This is a gravity flow system, greywater flows through:

- Anaerobic multi-layer of sand
- Coal
- Gravel. (Gravel layer consists of crushed limestone, bricks, and concrete).

"The amounts of water being treated using natural mechanisms, with low energy consumption with good results, has benefited the community and increase awareness on water conservation." (Palestine) Burnat and Eshtayah, 2010

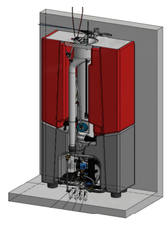


This works by warm greywater pumped into a wood chip bed creating a biologically active soil, trees and plants are close which benefit from nutrients and irrigation.

"Topsoil is a purification engine many times more powerful than engineering treatment plants, or even septic tanks, which discharge wastewater into the subsoil, below the treatment capacity" Art Ludwig, 2015.

Hydraloop, Designed in the Netherlands, a residential greywater recycling system. It works by collecting greywater and treats the water without filters or membranes.

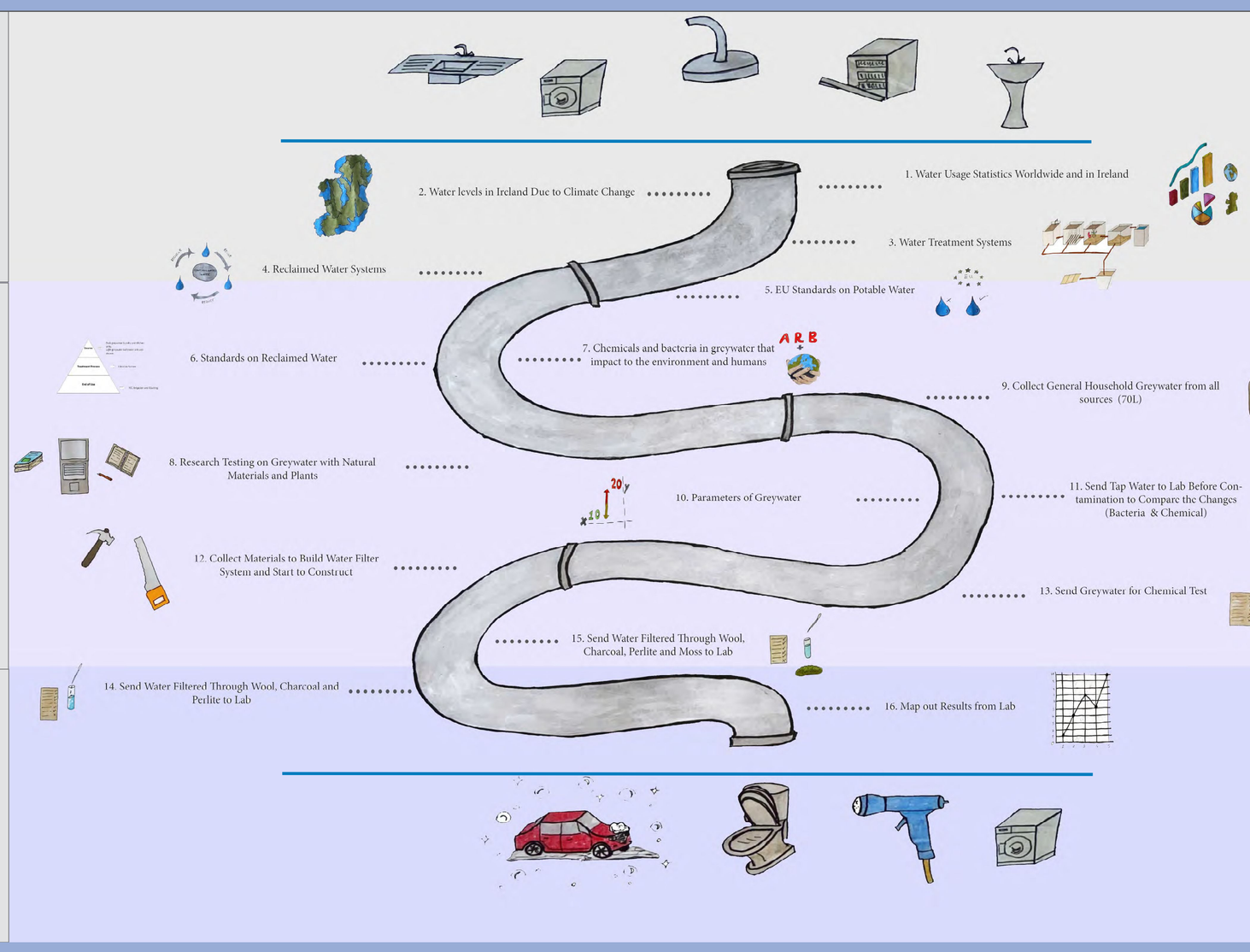
- Sedimentation,
- Flotation
- Foam fractionation
- Aerobic bioreactor
- UV light.



Water can be used for
- Toilet flushing
- Washing machine
- Garden
- Swimming pool

"It is estimated that the population of the world will reach 8.5 Billion, if just 5% of those people recycled water in their homes it stop the growth of water uptake on this planet. " Sabine Stuiver Co Founder of Hydraloop.

Thesis Timeline



09 Results

Micro: Changes to tap water after contamination

Greywater results compared to tap water

Ammonia +70%
Calcium +92%
Magnesium +90%
Nitrite +2%
Iron +100%
Manganese +6%
Total Hardness +90%
Colour +100%
Appearance and Odour Increased

Micro: Changes to greywater after filtration

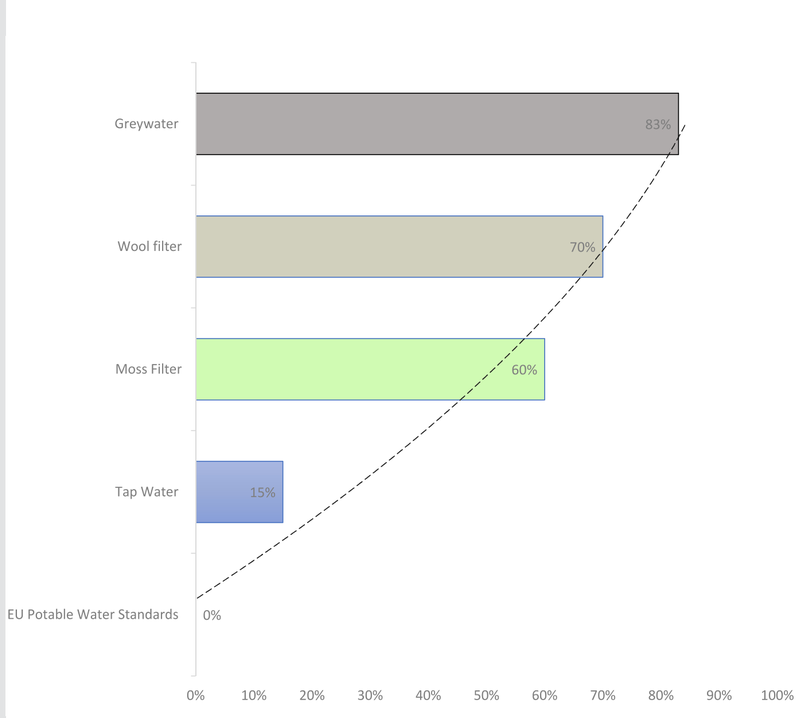
Wool Filter Results

Ammonia 35%
Calcium +43%
Magnesium 70%
Nitrite 7%
Iron 50%
Manganese 7%
Total Hardness 19%
Colour 16%
Appearance and Odour Reduced

Moss Filter Results

Ammonia 68%
Calcium 93%
Magnesium 100%
Nitrite 6%
Manganese 5%
Total Hardness 97%
Colour 40%
Appearance and Odour Reduced

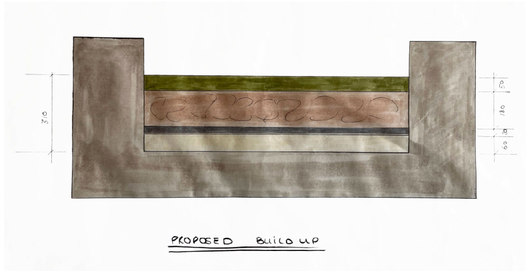
Macro: Filtered Water Comparison to Drinking Water



This chart shows how far away the water quality is from drinking water.

10 Recommendation

Results show that the a total build up of 50mm moss, 180mm wool, 20mm charcoal and 60mm perlite totaling to 310mm. Can successfully reduce greywater contaminates by 23%.



However, for this reclaimed water there is still a high iron level but is still under the total limit guidance. Manganese is still in high levels exceeding the total limits. It is important to be aware of bacteria counts in greywater and reclaimed water. Bacteria levels were not in the scope of this study.

According to BSRIA Water Reclamation Guidance, recommended levels of bacteria are controlled, with coliform limits specified. High levels of Iron and Manganese in water can cause reddish/black staining to laundry, cisterns and sinks. Its also well known to lower the affect of UV treatment systems.

A recommendation of further filtration would be needed to increase the end uses of the reclaimed water.

For this reclamied water a suggestion of installing:

- UV integrated system with pre filter (5 Macron Min)
- Vessel with Greensand prior to UV (Iron & Manganese)

Building Regulations on Reclaimed Water

In TGD Part H Drainage recommends following BSRIA Water Reclamation Guidance TN 6-2002 - Design and construction of systems using Greywater.

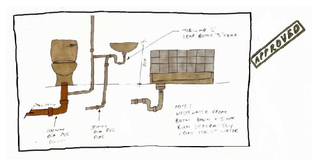
Extract from BS 1710:2014 Specification for identification of pipelines and services
Table F.2 Colours for water services

Pipe contents	Basic identification colour	Safety and Code Colours			Basic identification colour
Source of water					
Potable water derived from the public water supply (i.e. water undertaker)	Green	Auxiliary Blue			Green
Potable water derived from any other source (e.g. borehole)	Green	Flint Grey			Green
Water Quality					
Non-potable water system derived from any other source	Green	Flint Grey	Black	Flint Grey	Green
Non-potable water system derived from the public water supply	Green	Auxiliary Blue	Black	Auxiliary Blue	Green
Safety System					
Potable fire safety system derived from the public water supply	Green	Auxiliary Blue	Red	Auxiliary Blue	Green
Potable fire safety system derived from the any other source	Green	Flint Grey	Red	Flint Grey	Green
Non-potable fire safety system derived from the public water supply e.g. includes storage	Green	Auxiliary Blue	Black Red Black	Auxiliary Blue	Green

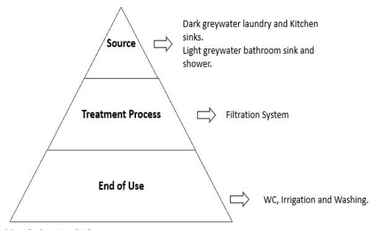
Colours and the widths of the basic, safety and code colour bands in these examples are for illustration only. Refer to BS 1710 and BS 4800 for the appropriate colour number and the dimension requirements.

Any pipework which has non potable water should be clearly identified according to the British Standards color of water services.

The reclaimed water system should follow British Standards Gravity drainage systems inside buildings.



When installing a reclaimed water system, if the building is connected or will be connected to mains water supply, the local county council are to be notified. A submission of detailed drawings or scheme for the proposed system. Once approved, then a reclaimed system is installed. (BRSIA Pg 8)



BSRIA Water Reclamation Guidance

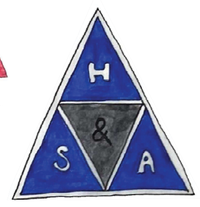
Maximum Concentraion of bacteria in reclaimed water

Applications	Class A Vehicle Washing Sprays	Class B Drip & sub-surface irrigation	Class C WC Flushing (no taps)
Water Quality Guidance. Total Coliforms cfu/l 100ml	10	1000	1000
Test Criteria. Total Coliforms cfu/l 100ml	1	100	100

TGD Part H Drainage, Table 12

In particular, when there is multi users with a reclaimed water systems, signs should be visible showing its non potable water.

Guidance by the Health and Safety Authority Ireland shows the codes of practice when working in hazard conditions, Personal Protection Equipment thats required to carry out



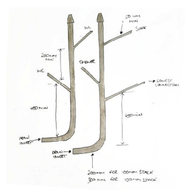
Three key areas for safety when installing and maintaning to consider:

Electrical Hazards

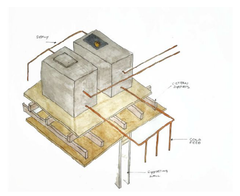
Biological Hazards

Chemical Hazards

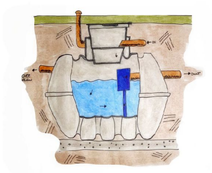
Pipework must be resistant to corrosion, recommended PVC or Brass fittings.



Separate stack vent where the grey-water feeds the reclaimed system. TGD Part H Drainage pg 9.



Separate cold water storage tank is needed for reclaimed water after treatment.

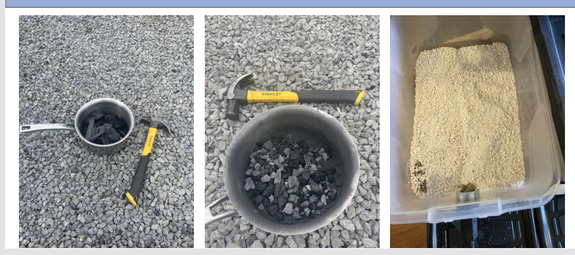


Greywater tank before treatment should be vented also and fitted with an overflow pipe.

07 Filter Construction

1. Setting out angles and lengths for timber frame on ground. Scale 1.1.
2. Timber frame mid assembly, preparing shelving to hold containers and stopping ends to keep containers in place.
3. Containers layed out on frame. Pre drilled holes then followed by stepped drill bit (pre heated to prevent cracking) opened out to accommodate the taps.
4. PVC taps Fitted with o-rings.
5. Drill holes for piping to connect to taps, to force the water to be filtered through the substrates from the bottom up.

Assembling Wool and Hemp Filters



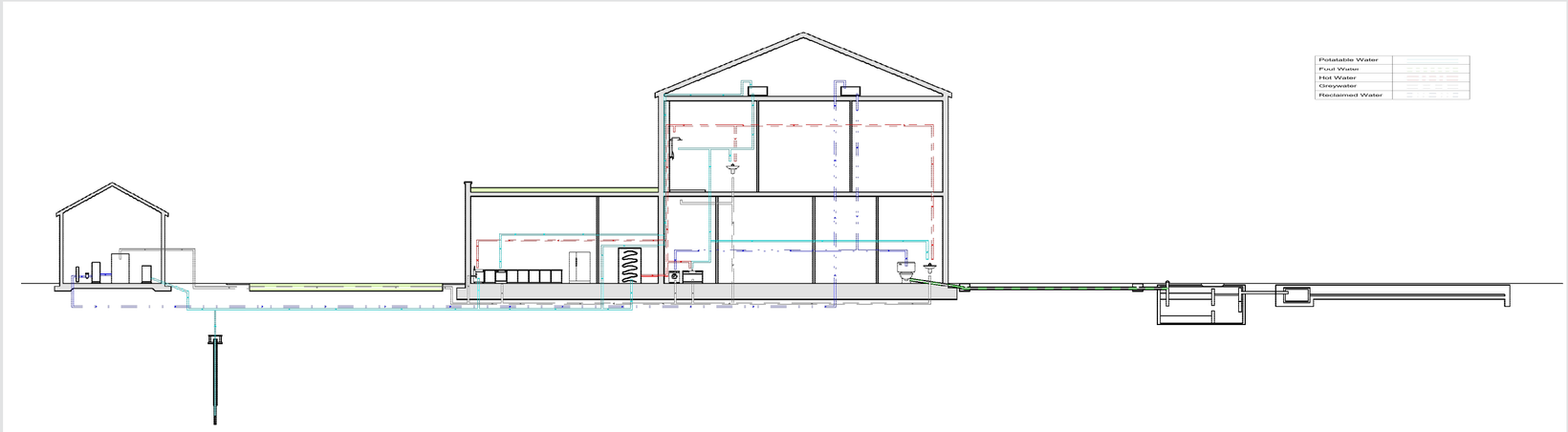
1. Crush Charcoal
2. Fill containers with a layer of perlite

1. Cut a layer of wool/hemp, place over perlite
2. Cover wool/hemp with charcoal
3. Fill the containers with the wool/hemp

Assembling Wool and Moss Filter

1. Crush Charcoal
2. Repeat wool filter
3. Repeat wool filter, exclude charcoal
4. Cut moss to size of container
5. Place moss in lower container

Potential: Domestic Water Services Scheme with Reclaimed Water System



Energy and Cost

It takes 0.92 K/watts per m3 of energy to treat wastewater, with a commercial energy rate of 39 cent per kWh and 1.05 million liters of wastewater was collected in the public sewage system a day in Ireland.

If 70% of that greywater was recycled a day, it would save an equivalent amount of energy that it takes to boil 350,000 thousand 3kw kettles.

11 Future Studies

- Areas such as green spaces and roofs
- Technical detailing of green roofs
- Flow rate capacity
- Variations to material thicknesses
- Weather impacts
- Installment costs
- Retrofitting Strategy

References

- Hydrology Monthly Bulletin Edition 034 Feburary, EPA (2023)
- Hydrology Monthly Bulletin Edition 035 March, EPA (2023)
- Europe's Water in Figures, An overview of the European drinking water and waste water sectors , EurEau (2021).
- Water Quality in Ireland 2010-2012, EPA (2012)
- Thomaidi et al., (2022) "Use of Green Roofs for Greywater Treatment: Role of Substrate, Depth, Plants, and Recirculation."
- Ludwig, (2008) Create an Oasis with Greywater.
- Barozzi, F. (2020) "Aquatic Mosses as Adaptable Bio-Filters for Heavy Metal Removal from Contaminated Water."
- Houses of the Oireachtas (2017) "Future Funding of Domestic Water Services Committee Publishes Report."
- WISE-Freshwater (2022)"Overview: Urban Waste Water Production and Its Treat-

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TECHNOLOGICAL UNIVERSITY DUBLIN

Can greywater be reused in a home?

01 Introduction

This study is to look at greywater produced at domestic level and to look at natural sustainable filtration methods that could be used to help reduce water waste by using re-claimed water where possible in a home.

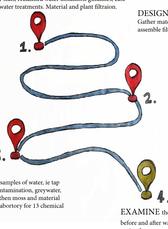
02 Aims

The Aim is to determine whats in greywater and how harmful is it to humans and the environment. Test how difficult it is to treat using simple, sustainable and natural raw materials. What standards can be achieved through natural filtration mediums. Compare the quality of greywater before and after filtration and tested to EU Potable water standards. To further develop technology to reduce water waste in homes. If the water can be reused? Where? Could this technology be applied in architecture design?

03 Objectives

RESEARCH EU potable water standards, EPA stats on water levels and natural water quality in irealnd, water uasage patterns, greywater stats, reclaimed water installtion guidlines, case studies on greywater treatments. Material and plant filtraion.

DESIGN filters and frame. Gather materials to construct. assemble filters for greywater.



COLLECT samples of water, ie tap water before contamination, greywater, material filters then moss and material filters, send to laboratory for 13 chemical test.

EXAMINE the changes to water before and after water filtration. Categories the reuses of the water, energy reduction by reusing greywater.

04 Motivation

As an Architectural Technology Student, the role is to attempt to identify and provide solutions for problems in Residential, Commercial, and the Industrial Sector. Not only the performance of a building is important but how a buildings existence impacts the environment. It is well known that water resources availability varies across the country. Under growing pressure from population increase, increasing demand and climate change. With an interest in water quality and a background in water drilling as a family business. I know the importance in the need for clean water and sanitation. It is a natural resource that needs to be respected. There's a natural cycle of water and by human impact it can have a knock-on effect which can lead to contamination either in ground water and flowing waters.

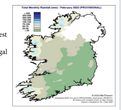
05 Scope

The scope of this study is to look at how water is used in Ireland in a domestic setting. The chemical contaminates in greywater. To attempt to filter greywater to the best level possible, for reuse within a home which is not potable water. The focus is to look at the water usage in a typical domestic home globally and in Ireland.

06 Literature Review

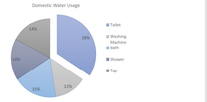
> "By 2025, nearly 1.8 billion people will live in areas with absolute water scarcity, and two thirds of the world population could face water-stressed conditions." United Nations Press Release March 2016.

In the EPA Monthly Hydrology Bulletin Report, Februuary was reported the driest month in years. Rainfall averages were below the normal range Across the country. In County Wexford it was its driest Februuary since 1986. However , March rainfall was Above average around the country. Reports in Donegal Had seen precipitation exceeding 227% and Dublin Airport reported its wettest march since 1947.



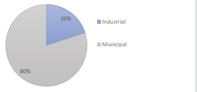
"Ireland is ranked 10th highest of 25 European Union countries, excluding Latvia and Lithuania, for household water consumption". Eureau, Europe's water in figures.

"In November 2021, European Commission referred Ireland to the Court of justice of the European Union for failure to comply with the requirements of Drinking Water Directive." "This applies to water management supplying towns and cities but also the source of water ie; lakes, rivers and reservoirs."



It is estimate that 70% of clean potable water is output as greywater. Based on water usage patterns in a typical household in Ireland, at least 370 Liters of greywater that could be recycled, is mixed in sewage everyday.

The main source of serious pollution in Ireland according to the EPA is:



Water quality describes the condition of the water and its characteristics. **Water standards** categories the condition of the water into levels that are for its use and consumption. The **EU** sets out guidance on the Maximum Admissible Concentrations in Waters for Potable Use.

Greywater

Light
Bathroom
Contains Shampoos, body care products, hair, lint
Washbasin
Contains soap, toothpaste, body care products, shaving waste and hair
Dark
Laundry
Contains Soap, Bleach, oils, Paints, Solvents, and Non Phosphates
Kitchen Sinks
Contains Food Residue, High amounts of oil and fats, dishwasher detergent.

Did you Know?
The public water service in Ireland provide drinking water to over 80% of the population, delivering on average 2000 million litres of water each day.

What's in Greywater?

Greywater is what once was clear drinking quality water, is introduced with detergents, chemicals, metals, bacteria, lint from fabrics and other particles.

Why is Greywater harmful?

Chemicals when released into the environment ie; Septic tanks (30% of Ireland's Population) and land disposal, which Ireland disposes of 80% of its waste sludge via agriculture. Plus from general contamination as shown in chart from EPA.

This can cause:

- Spikes in harsh chemicals, phosphorous which cause algae blooms,
- High levels of nitrates , which leads to fish kills, damaging ecology and vegetation.

(Ireland is about 45% compliant with sewage treatment in line with EU legislation).

Waterborne diseases is when bacteria enters water. Bacteria living in harsh environments such as heavily chemical contaminated water can evolve and become antibiotic resistant bacteria known as ARB making illness difficult to treat.

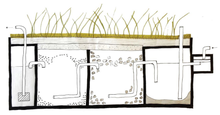
> "It's absurd that in the 21st century people still keep flushing their toilets with precious water, as it is becoming scarcer every day." Arthur Valkieser
> Founder of Hydraloop.

Case Studies

A study on green roofs in the Greek Islands:

- Plants such as, Geranium, Mediterranean Salt Bush, Myrtle-leaf milkwort.
- Substrate of Perlite, Vermiculite and Clay.

Results suggest that intensive green roofs filled with 20 cm of vermiculite and 5 cm of LECA (baked clay) could treat efficiently light greywater.



This is a gravity flow system, greywater flows through:

- Anaerobic multi-layer of sand
- Coal
- Gravel. (Gravel layer consists of crushed limestone, bricks, and concrete).

"The amounts of water being treated using natural mechanisms, with low energy consumption with good results, has benefited the community and increase awareness on water conservation." (Palestine) Burnat and Eshtayah, 2010

This works by warm greywater pumped into a wood chip bed creating a biologically active soil, trees and plants are close which benefit from nutrients and irrigation.

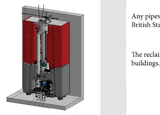
"Topsoil is a purification engine many times more powerful than engineering treatment plants, or even septic tanks, which discharge wastewater into the subsoil, below the treatment capacity" Art Ludwig, 2013.

Hydraloop, Designed in the Netherlands, a residential greywater recycling system. It works by collecting greywater and treats the water without filters or membranes.

- Sedimentation,
- Flotation
- Foam fractionation
- Aerobic bioreactor
- UV light.

Water can be used for

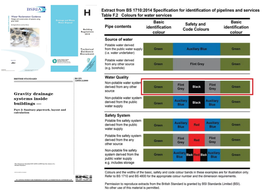
- Toilet flushing
- Washing machine
- Garden
- Swimming pool



> "It is estimated that the population of the world will reach 8.5 Billion, if just 5% of those people recycled water in their homes it stop the growth of water uptake on this planet." Sabine Stuiver Co Founder of Hydraloop.

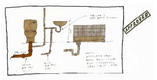
Building Regulations on Reclaimed Water

In TGD Part H Drainage recommends following BSRIA Water Reclamation Guidance TN 6-2002 - Design and construction of systems using Greywater.



Any pipework which has non potable water should be clearly identified according to the British Standards color of water services.

The reclaimed water system should follow British Standards Gravity drainage systems inside buildings.



When installing a reclaimed water system, if the building is connected or will be connected to mains water supply, the local county council are to be notified. A submission of detailed drawings or scheme for the proposed system. Once approved, then a reclaimed system is installed. (BRSIA Pg 8)

Maximum Concentraion of bacteria in reclaimed water

Applications	Class A: Vehicle Washing Sprays	Class B: Drip & sub-surface Irrigation	Class C: WC Flushing (no taps)
Water Quality Guidance. Total Coliforms cfu/l 100ml	10	1000	1000
Test Criteria. Total Coliforms cfu/l 100ml	1	100	100

TGD Part H Drainage, Table 12

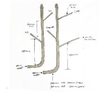
In particular, when there is multi users with a reclaimed water systems, signs should be visible showing its non potable water.

Guidance by the Health and Safety Authority Ireland shows the codes of practice when working in hazard conditions, Personal Protection Equipment thats required to carry out

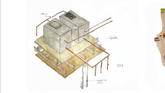
Three key areas for safety when installing and maintaning to consider:

Electrical Hazards Biological Hazards Chemical Hazards

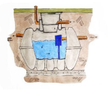
Pipework must be resistant to corrosion, recommended PVC or Brass fittings.



Separate stack vent where the greywater feeds the reclaimed system. TGD Part H Drainage pg 9.



Separate cold water storage tank is needed for reclaimed water after treatment.



Greywater tank before treatment should be vented also and fitted with an overflow pipe.

Plant Filtration

Location: Ardcarnown County Westmeath

Moss Facts

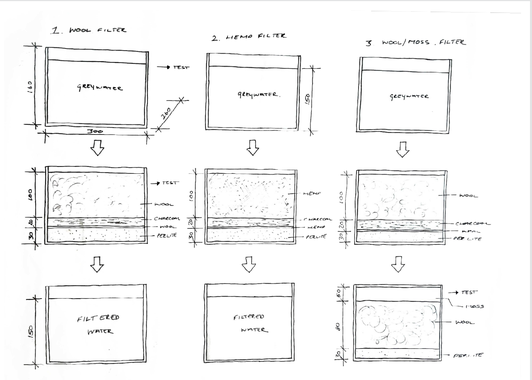
- Mosses are non-flowering plants which produce spores and have stems and leaves, but don't have true roots.
- Classified as Bryophytes
- Mosses grow in many different environments, can adapt to inhabitable areas.
- Mosses function like sponges, using their capillary spaces to hang on to water.

Phytoremediation

Phytoremediation is when plants uptake contaminants such as metals, pesticides and chemicals. Moss, with gametophyte characteristics, can act as live filtering material.

Material Filtration

Filter Design

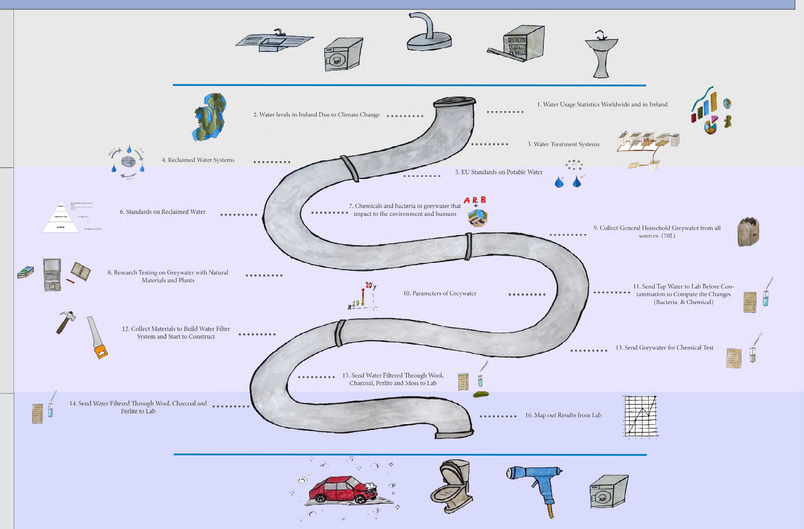


Researching filtration systems for greywater. The case study on green roofs in the Greek Islands, has shown success in the treatment of light greywater. This inspired further research into plant and natural material filtration which led to the prototype tested in this study.

The section shows, the layout of the filters, the thickness of the materials and at what stage testing is carried out. The water is gravity fed to the bottom of the container which forces the water to filter through the mediums , then overflow into the next container, where the water is collected. The filters are supported on a three tier frame which elevates the containers to improve the water flow. The filters consisted of wool, hemp, perlite, charcoal, and native Irish feather moss (Eurhynchium striatum).

For the moss layer it could not be submerged in water (previous trial over a period of weeks submerged in greywater showed the moss would not survive) so as a prop for the moss to be at the waterline, a layer of perlite and wool was added.

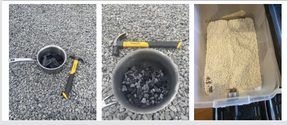
Thesis Timeline



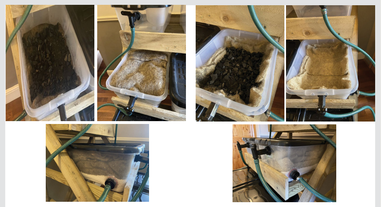
07 Filter Construction

1. Setting out angles and lengths for timber frame on ground. Scale 1.1.
2. Timber frame mid assembly, preparing shelving to hold containers and stopping ends to keep containers in place.
3. Containers layed out on frame. Pre drilled holes then followed by stepped drill bit (pre heated to prevent cracking) opened out to accommodate the taps.
4. PVC taps Fitted with o-rings.
5. Drill holes for piping to connect to taps, to force the water to be filtered through the substrates from the bottom up.

Assembling Wool and Hemp Filters



1. Crush Charcoal
2. Fill containers with a layer of perlite



1. Cut a layer of wool/hemp, place over perlite
2. Cover wool/hemp with charcoal
3. Fill the containers with the wool/hemp

Assembling Wool and Moss Filter

1. Crush Charcoal
2. Repeat wool filter
3. Repeat wool filter, exclude charcoal
4. Cut moss to size of container
5. Place moss in lower container

Previously testing the wool filter, there was a problem when the water was filtering through the perlite and wool, the materials were dry and light, so it began to float rather than soak the water. These brackets prevent that and allow the water to penetrate through the material and keep in place.

The hemp filter did not improve the water quality from a visual point and the odor of the water was intensified. Sample strips indicated a rise in nitrogen. Therefore, a decision was made to not test the hemp filter further. However, the wool did show improvements visually and therefore laboratory testing were carried out.

Preliminary Testing Only

- A data sheet was made on Excel.
- 3 test strips were carried out for each sample of water, the results were aggregated to an overall average.

Results can vary, overall if levels in any parameters were very high it would indicate so. For accuracy the laboratory results are to be analyzed, with conclusion.

Parameter	Hemp 1A	Untreated Greywater	Tap Water	Treated Tap Water	Wool	Wool + Moss	Limits
Total Alkalinity	>120	180	180	0	180	>40	120
PH	>8.4	8.4	8.4	6.2	8.4	>6.2	7.2-7.8
Hardness	250	250	500	250	250	50	250-500mg/l
Cyanuric Acid	30-50	30-50	30-50	<30	30-50	0	0-50mg/l
Total Chlorine	0	0	0	0	0	0	0mg/l
Free Chlorine	0	0	0	0	0	0	0-1mg/l
Free Bromine	0	0	0	0	0	0	0-1mg/l
Nitrate	0	0	0	0	0	0	0-10mg/l
Nitrite	0	1	0	0	0	0	0-1mg/l
Iron	0	0	0	0	0	0	0mg/l
Chromium	0	0	0	0	0	0	0-2mg/l
Lead	0	0	0	0	0	0	0mg/l
Copper	0	0	0	0	0	0	0mg/l
Mercury	0	0	0	0	0	0	0mg/l
Fluoride	0	0	0	0	0	0	0mg/l
Carbonate Rest	80	80	80	20	80	20	0-20mg/l

08 Testing

Testing will be carried under laboratory conditions, by Oldcastle Laboratories, certified in testing potable water to EU Standards.

Testing As Follows:

- Stage 1, the testing of tap water before contamination.
- Stage 2, the testing of untreated greywater collected from various sources such as (kitchen sink, bathroom sink, shower, bath, washing machine and dishwasher).
- Stage 3, the testing of the materials filters (wool, charcoal, and perlite).
- Stage 4, the testing with moss added as a filtration layer.

List of 13 parameters sample are tested to. Samples are tested against the highest water quality (potable drinking water).

	Parameter	Total Limit	Test Method
	Chemicals		
1	Ammonia	0.3mg/l	TM2118
2	Calcium	200mg/l	TM2129**
3	Maganeisium	50mg/l	TM2129**
4	Nitrite (NO2)	0.3mg/l	TM2118**
5	Nitrate (NO3)	11.3mg/l	TM2216
6	Iron	200µg/l	TM2116**
7	Manganese	0.05mg/l	TM2121**
8	Conductivity	2500µS/cm (Siemens per centimetres) @20Deg	TM2132**
9	Total Hardness	N/A	TM2126**
10	Appearance	N/A	TM2218**
11	Colour	20 Unit PtCo	TM2126**
12	Odour	N/A	TM2121**
13	PH	No Less PH 6.5 , No High PH 9.5 @ 20Deg	TM2128**

09 Results

Micro: Changes to tap water after contamination

Greywater results compared to tap water

Ammonia +70%
Calcium +92%
Magnesium +90%
Nitrite +2%
Iron +100%
Manganese +6%
Total Hardness +90%
Colour +100%
Appearance and Odour Increased

Micro: Changes to greywater after filtration

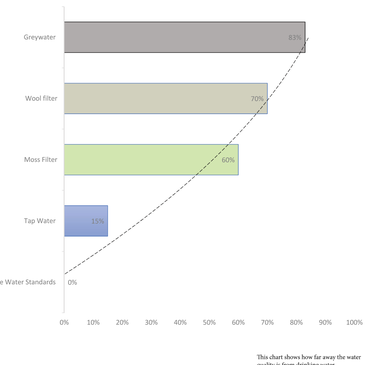
Wool Filter Results

Ammonia 35%
Calcium +43%
Magnesium 70%
Nitrite 7%
Iron 50%
Manganese 7%
Total Hardness 19%
Colour 16%
Appearance and Odour Reduced

Moss Filter Results

Ammonia 68%
Calcium 93%
Magnesium 100%
Nitrite 6%
Manganese 5%
Total Hardness 97%
Colour 40%
Appearance and Odour Reduced

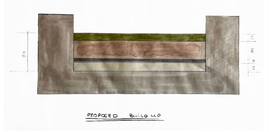
Macro: Filtered Water Comparison to Drinking Water



This chart shows how far away the water quality is from drinking water.

10 Recommendation

Results show that the a total build up of 50mm moss, 180mm wool, 20mm charcoal and 60mm perlite totaling to 310mm. Can successfully reduce greywater contaminates by 23%.



However, for this reclaimed water there is still a high iron level but is still under the total limit guidance. Manganese is still in high levels exceeding the total limits. It is important to be aware of bacteria counts in greywater and reclaimed water. Bacteria levels were not in the scope of this study.

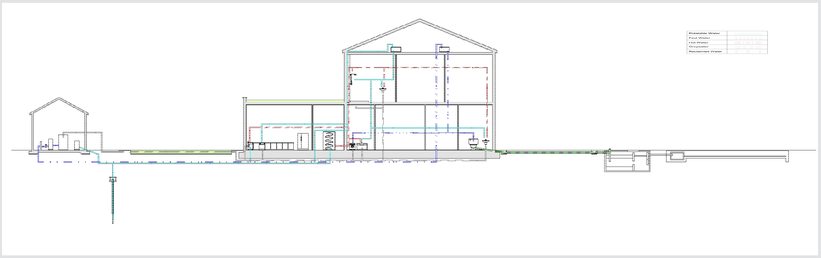
According to BSRIA Water Reclamation Guidance, recommended levels of bacteria are controlled, with coliform limits specified. High levels of Iron and Manganese in water can cause reddish/black staining to laundry, cisterns and sinks. Its also well known to lower the affect of UV treatment systems.

A recommendation of further filtration would be needed to increase the end uses of the reclaimed water.

For this reclamied water a suggestion of installing:

- UV integrated system with pre filter (5 Macron Min)
- Vessel with Greensand prior to UV (Iron & Manganese)

Potential: Domestic Water Services Scheme with Reclaimed Water System



Energy and Cost

It takes 0.92 KJ/watts per m3 of energy to treat wastewater, with a commercial energy rate of 39 cent per KWh and 1.05 million liters of wastewater was collected in the public sewage system a day in Ireland.

If 70% of that greywater was recycled a day, it would save an equivalent amount of energy that it takes to boil 350,000 thousand 3kw kettles.

11 Future Studies

- Areas such as green spaces and roofs
- Technical detailing of green roofs
- Flow rate capacity
- Variations to material thicknesses
- Weather impacts
- Installment costs
- Retrofitting Strategy

References

- Hydrology Monthly Bulletin Edition 034 Feburary, EPA (2023)
- Hydrology Monthly Bulletin Edition 035 March, EPA (2023)
- Europe's Water in Figures, An overview of the European drinking water and waste water sectors , EurEau (2021).
- Water Quality in Ireland 2010-2012, EPA (2012)
- Thomaidi et al., (2022) "Use of Green Roofs for Greywater Treatment: Role of Substrate, Depth, Plants, and Recirculation."
- Ludwig, (2008) Create an Oasis with Greywater.
- Barozzi, F. (2020) "Aquatic Mosses as Adaptable Bio-Filters for Heavy Metal Removal from Contaminated Water."
- Houses of the Oireachtas (2017) "Future Funding of Domestic Water Services Committee Publishes Report."
- WISE-Freshwater (2022)"Overview: Urban Waste Water Production and Its Treat-

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