THE BIGGER PICTURE On Plastics

USING CITIZEN SCIENCE TO ANALYSE MICROPLASTICS EMPOWERING CITIZENS TO CREATE CHANGE

Project Summery

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1 | River Research

This project research first started with analysis into the relationship western society has with rivers. Rivers were chosen as an example of our unbalanced relationship with natural systems due to the unique cross-section of society that is directly touched by the physical presence of rivers as they run from rural through suburban to urban settlements. This research stretched between the social-political relationships to the technical understanding of pollution.

river health and human interaction comparison

Comparison of rivers under analysis to rivers (or models) unaffected by human interaction is essential to understandings river health (Milne. Ian, SEPA, 2019). This understanding of how human interactions with river environments affects the health of the river is paramount to protecting rivers from ongoing and future harm (Karr, 1999).

River Visits

WIthin river site visits it was found that as other forms of pollution decrease plastic pollution has increased at an alarming rate. With microplastics often being “out of sight out of mind”.

Interviewees

Richard Brown – SEPA Hydrologists
Ian Milne – SEPA Biologist
Manousos Valyrakis – River Hydrologist
Fiona Nichols – Greenpeace Microplastic Researcher
Brian Quinn – Head of Microplastic Research Group
Frabrice Renaud – Microplastic Scientist
George Parsonage - Glasgow Humane Society

Most Influential Reading

Anderson, J. C. Microplastics in aquatic environments: Implications for Canadian ecosystems
Bergmann, M. Synthetic and non-synthetic anthropogenic fibers in a river under the impact of Paris Megacity: Sampling methodological aspects and flux estimations
Li, J. Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastics detection

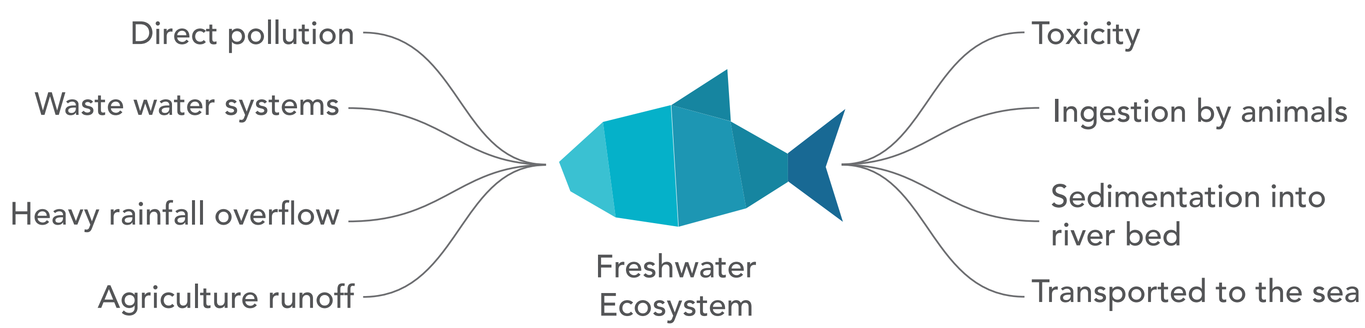
Between 3.8 -10.2 Million Tons of plastic enter the ocean from rivers each year

lack of scientific understanding on microplastics

There is a lack of understanding of the abundance, fate, behaviour and effect of microplastics on and in freshwater systems (Anderson et al., 2016; Dris et al., 2018; Liedermann et al., 2018; Tibbetts et al., 2018).

This is in part due to the complexity of interactions within environmental systems, the limited number of studies relative to this and the lack of standardization which in turn leads to the lack of ability to compare results and create a cohesive understanding. Microplastic testing is further limited as it often difficult to do; time consuming to sample; while requiring an extensive process to remove and identify the plastic from organic matter. Due to the highly variable environment of rivers across time and social-geographically once data is collected it is then difficult to reliably quantify.

microplastics: Fibres | Fragments | Bead/Pellets

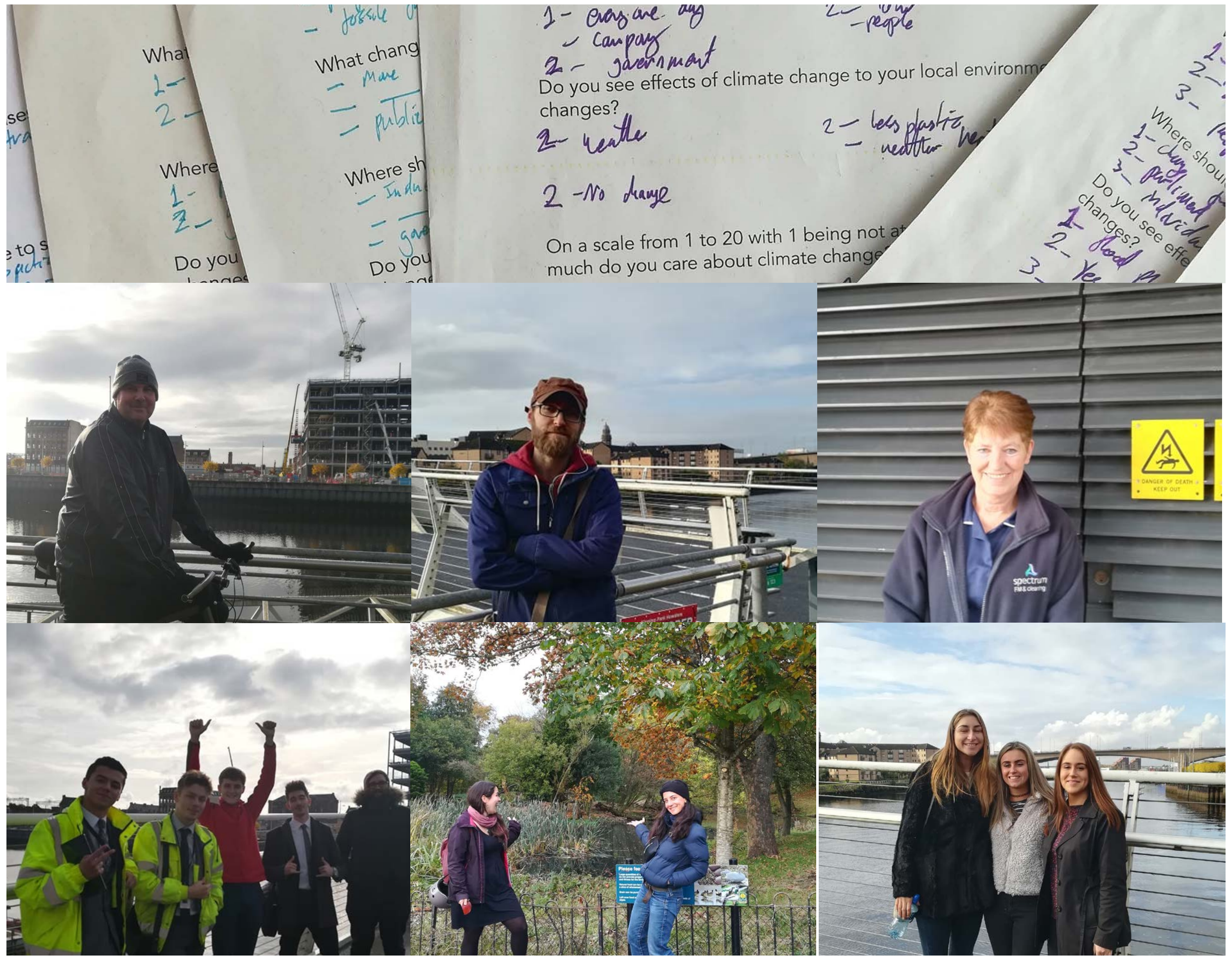


2 | River Research

A simple survey was used to identify the general Zeitgeist round plastic pollution, the cause, extent and opinion. This was taken at the River Kelvin and the Clyde.

lack of public awareness about microplastic pollution

It was found that there was a general lack of public awareness about microplastic pollution within rivers despite the recent David Attenborough effect (GlobalWebIndex, 2019). It was also found that people were passionate about the way in which society negatively impacts the environment in relation to animals and future generations.



Interviewees

Fiona Nichols – Greenpeace Microplastic Researcher
Connie Arnold – Greenpeace Glasgow Coordinator
Greenpeace Glasgow Group
Louise Broach – Up Stream Battle Chair
Danielle Banks – The Earth Wants You Back
Sally – Friends of the River Kelvin Chair
Friends of The River Kelvin Members
Sebastian Seeney – Greenpeace UK Ocean Lead
John Thorn - GSA Sustainability

Most Influential Reading

Greenpeace UK. UPSTREAM : Microplastics in UK Rivers.
Karr, J. R.. Defining and measuring river health. Freshwater Biology, 41(2), 221–234.
Mark Kinver. Reconnecting with nature "triggers" eco-action
Victor Papanek. The Green Imperative

Communicating results of biological monitoring to citizens and political leaders is critical if biological monitoring is to influence environmental policies

- James R. Karr (1999)

campaign methods

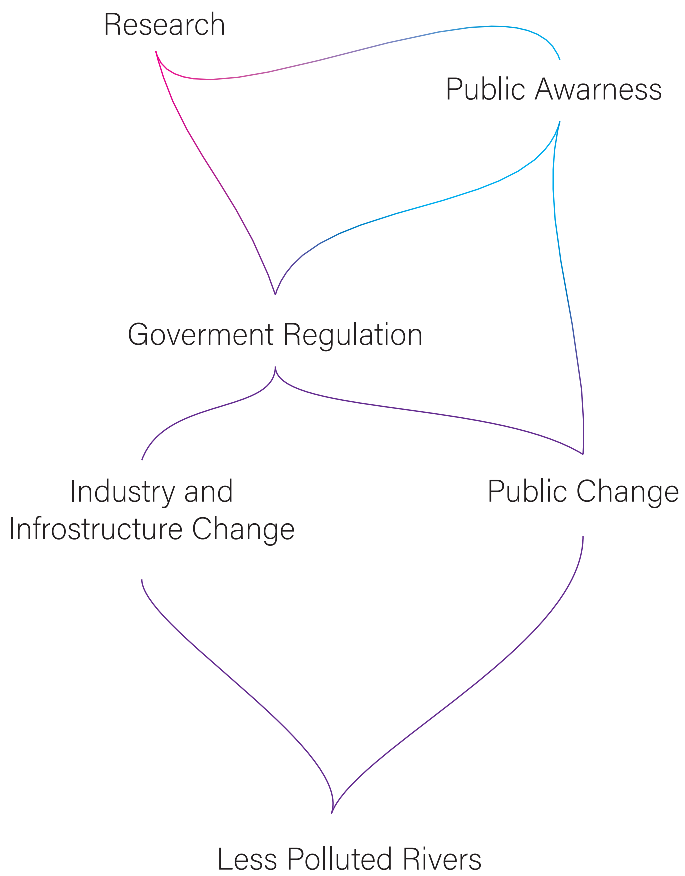
political lobbying
petitions
litter picks
leafleting
re-branding
public engagement
social media campaigning
litter picks
citizen science

successful campaigns

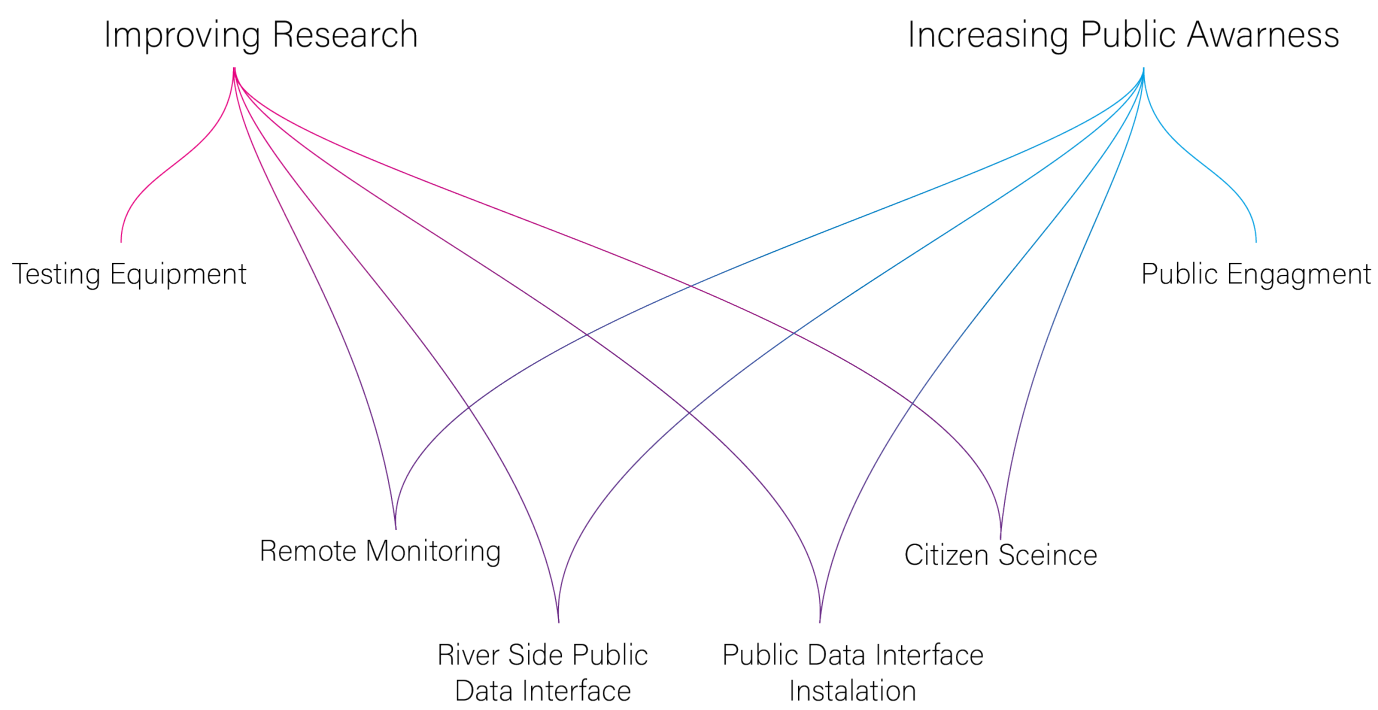
reduction ban

the way change happens to cleaner and healthier rivers

It was found through the combination of conversations with those who have seen and monitored the river changes, environmental activists, social scientists, microplastic scientists and case studies of change that change is a complex set of relationships. It takes a blend of research/ monitoring about the issue coupled with increased public awareness to create pressure for larger change.

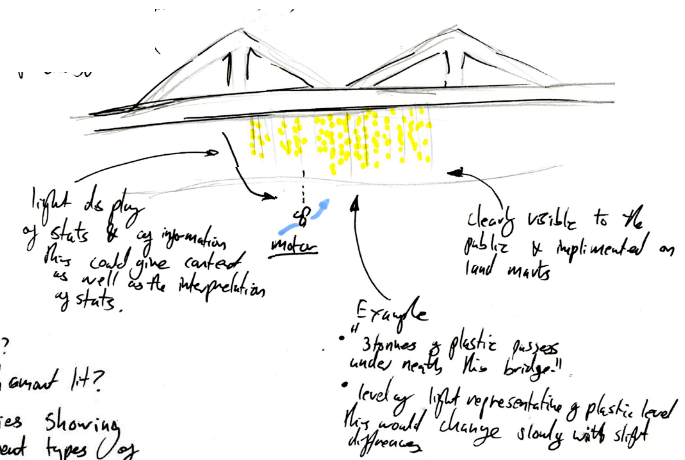


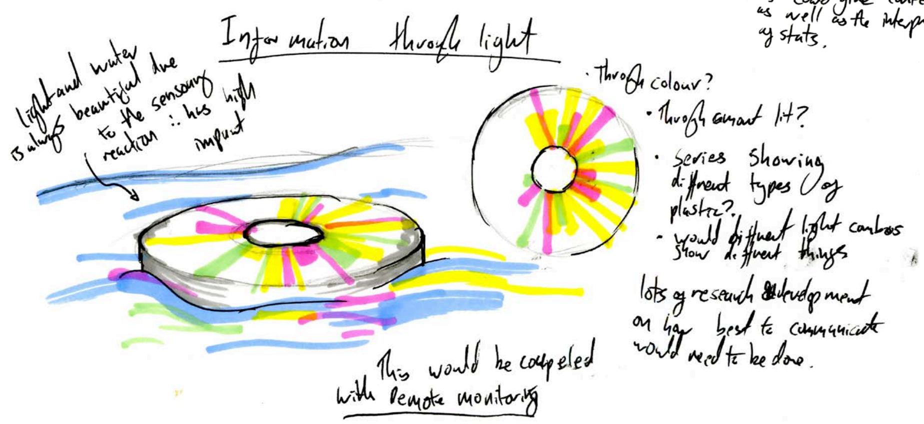
3 | Project Direction



The main directions explored within define, were remote monitoring (with the possibility of public data interface), testing equipment and citizen science, due to the level at which these ideas could address the needs outlined in the initial research.

remote monitoring

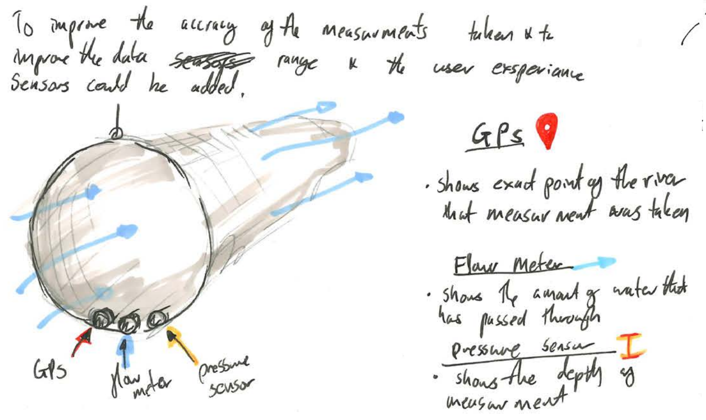


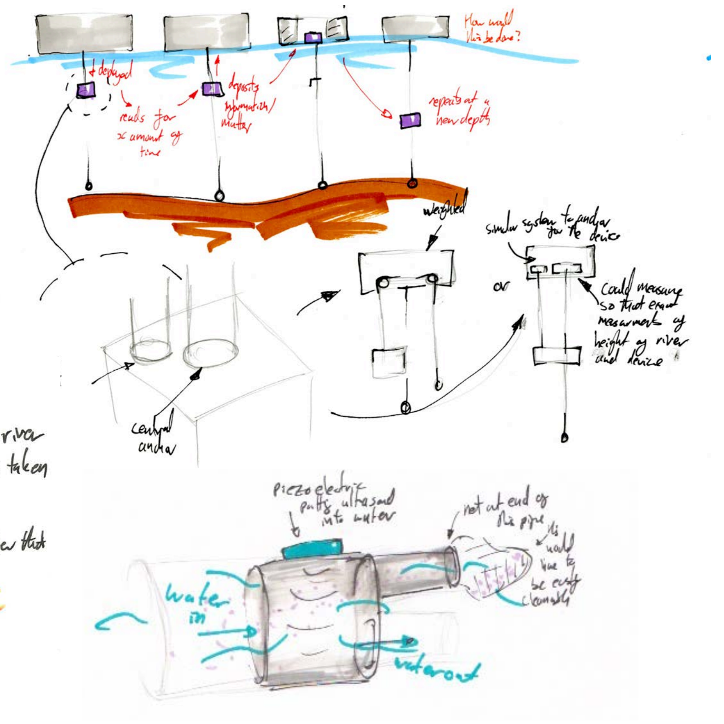


Initial technology proposed for this was ultrasound to image and identify the shape and/or density of plastic pollution, however the properties are not distinct enough from sediment to accurately identify the plastic.

Remote monitoring was found through technology and process research along with idea development not to be possible due to the level of detail needed for plastic identification requiring Fourier Transform Infrared Imaging (FTIR) analysis along with organic and inorganic separation (Li et al., 2018). In the given time frame of the project it would not be possible to develop this process into a remote monitoring station.

testing equipment

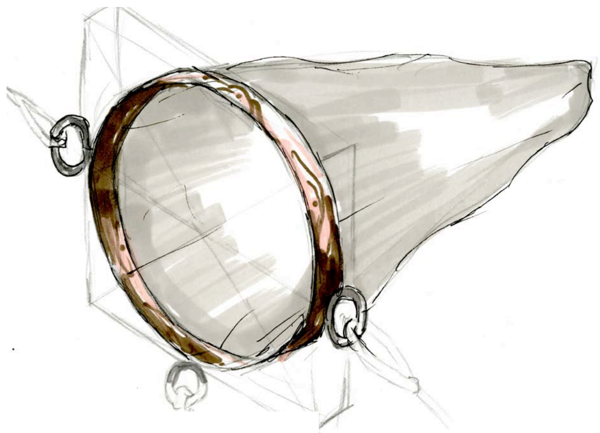


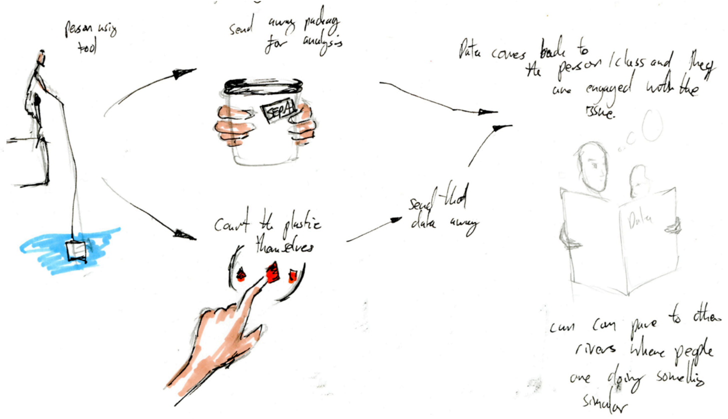


Ways to improve the current equipment that were considered were to increase the validity of results using standardised deploying, sensors to track the flow and pressure change and to improve the separation of plastic and organic material using ultrasound vibrations through the water.

While there was considerable need found within the initial research phase of the project for improved microplastic research tools it was found in interviews with microplastic researchers that the cost of the proposed initial ideas would outweigh the benefit to the sampling data due to already tight research budgets and the variability of rivers (Quinn.B, 2019. Renaud. F, 2019).

citizen science





It was therefore found in the project direction review that citizen science would be the most effective and probable way to improve understanding and increase public awareness of microplastics in freshwater systems. This research method collects vast data that would otherwise be impossible in the time frame and budget of traditional sampling while also engaging citizens in the issues in a way that is considerably more engaging and impactful that the traditional linear and media-based information route.

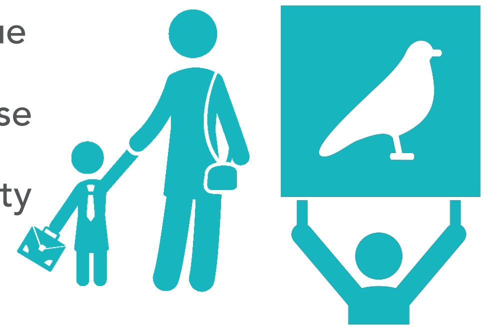
The kids would absolutely love this.

- Lisa Perrie

This fits perfectly with the new idea of education.. to empower and encourage investigation.

- Helen Brown

The user groups were identified as schools and environmental groups as they would be enthusiastic to use the kit due to the educational and environmental benefits. To ensure that the kit and the surrounding system would adhere to their needs, reading and interviews where carried out to identify them. These users were returned to within the project for feedback at the idea developed.



Interviewees

Helen Brown – Lead Officer Education Scotland
Kids at Curiosity Live
Kirsty Crawford – Project Officer Education: Citizen Science
Sam Langford – Science Learning Coordinator
JP Murry – Design Teacher Eastwood High School
Lisa Perrie – Sunnyside Primary Head Teacher
Duncan Smith – Science Education Coordinator
Kenny Torrance – Science Teacher Eastwood High School
Nina Morrison - Geography Graduate
Louise Broach – Up Stream Battle Chair

Most Influential Reading

Alexandra Lang. The Design of Childhood
Duncan Smith. What Makes a Good Hands-On Exhibit?
John Tweddle. UK Environmental Observation Framework, Guide to Citizen Science

To understand better the process and user journey of citizen science I analysed current projects using this method. This was done by participating in a litter pick with citizen science element of a count, interviewing the designer of a the Upstream Battle citizen science campaign and looking at a range of project's methods for gathering information.

successful methods

- established subject matter enthusiasm
- physical interaction
- minimal data input
- connection to larger meaning

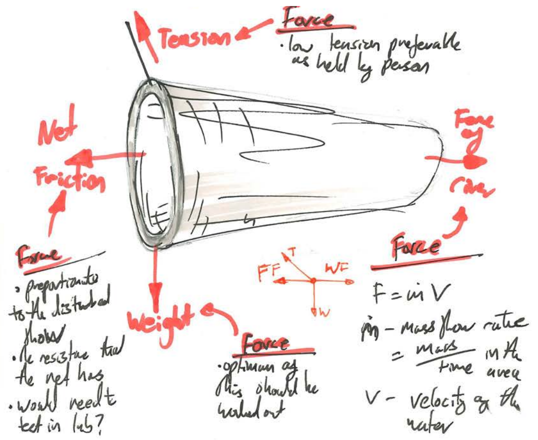
5 | Initial Concepts

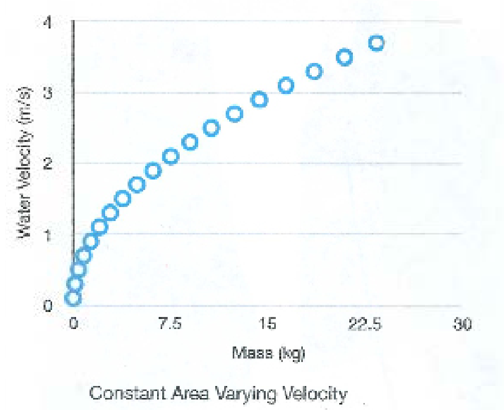
idea 1

The first iteration of prototypes was based on the manta net/trawl - a method of allowing river water to pass through netting to capture both fragments and fibres - commonly used to sample microplastics in freshwater. The popularity of this method is evident - a 2017 paper reviewing microplastic freshwater systems sampling methods reported 50% use (Li et al., 2018). These 100 micron-mesh and cheese cloth prototypes where tested both in a semi-urban river and an urban river.

idea 1

This method did not capture plastics, in part due to the resistance force of the net and supporting structure within the water causing a disruption to the flow therefore limiting the amount of debris that will enter the net and creating underestimation of the abundance of plastic. This resistance force also made it difficult to fully submerge into the water, weight needed to do so calculated below.



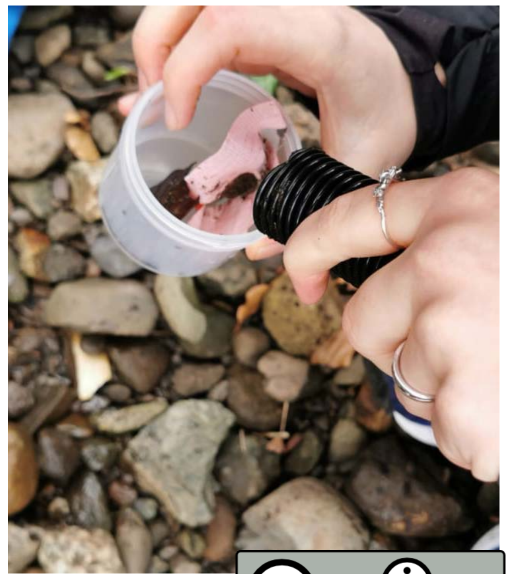


idea 2

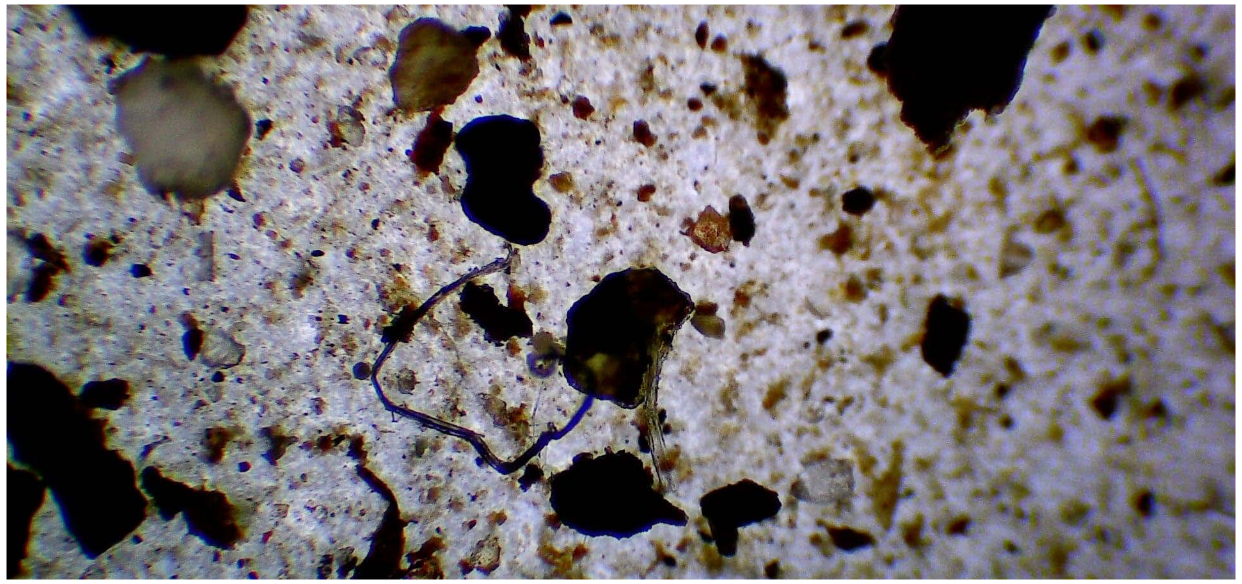
The results of the field test of idea 1 being unsuccessful in part due to the resistance lead to the development of idea 2 which would actively pump the water through the netting/mesh. The pump would pull the water up faster than the speed of the flow therefore removing the resistance and positive hydraulic pressure within the inlet.
After research into the design and engineering of different pumps I reached the iteration of a hand-held pump which draws water from the river on a pull stroke and pushes the water through filter mesh on the push stroke. This design was tested in the field using a prototype created by altering the design of a kayak pump - filtering mesh of 100 micron pour size was attached to the outflow of the pump

idea 2

This method of sampling picked up considerable amounts of sediment (that in first observation had no microplastics), this made the sample unpleasant to handle and would require a pre-filter for larger stones. For sampling of varied rivers this prototype would need longer or modular lengths of hose that would increase the work-done needed to take a sample and would introduce a degree of sample variability that would lower the data validity.



6 | Initial Concepts

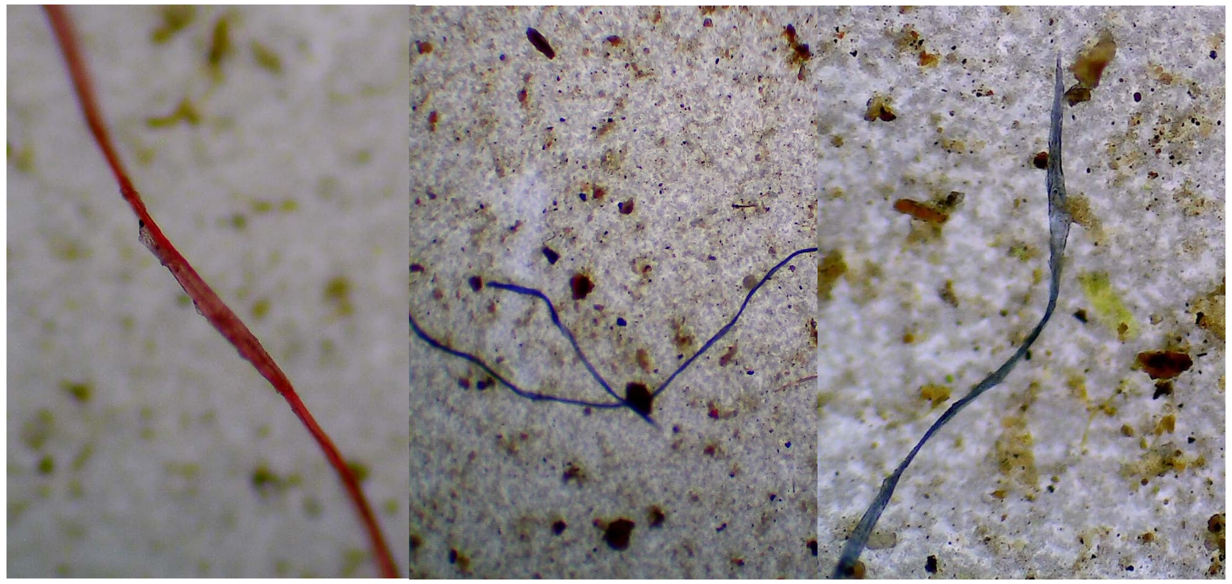


idea 2

It was found when analysing samples within micro-laboratory that the filter mesh size was too large (despite being smaller than many tests reviews in Jingyi Li paper) to capture the type of microplastics that are abundant within rivers. The finer filter mesh that would be needed to capture the plastics found, would need significantly higher forces to pump through the mesh due to the resistance forces caused by the disturbance to flow and the high surface tension that would be created by the porous nature of the material.

idea 3

The results of the field test of idea 2 finding microfibres within both sediment and suspended sediment led to research into testing sedimentation tools and methodology and then subsequently the development of an idea based upon the simplification of ridged body suspended-sediment samplers. To test the feasibility of this idea on a citizen scale product a simple field experiment was conducted by taking a river water sample and repeating laboratory analysis. This sample was taken from the same location to allow for results comparison between the methods and success of prototypes.



idea 3

The results of this were extremely shocking, showing an overwhelming abundance of microplastic fibres within the sample. The level of abundance was unexpected due to the rural location of the river with no large towns or settlements being in the river basin, indicating that plastic fibres are well established in the water systems a sign of the scale of the problem.

The level at which the results of this experiment where upsetting was heightened by my emotional connection to this location. This user experience is of great value and can be used to distil passion and/or anger for change

35 Pieces per 100ml when found in the River Kelvin

Therefore in a mean flow day approximately

34,600,000

plastic pieces through the river **every second**

To ensure that the concept worked in both rural and urban areas a second test was done in the River Kelvin. There were also plastics within this sample identifiable through the unnatural colour and shape.

concept and prototype found to be successful

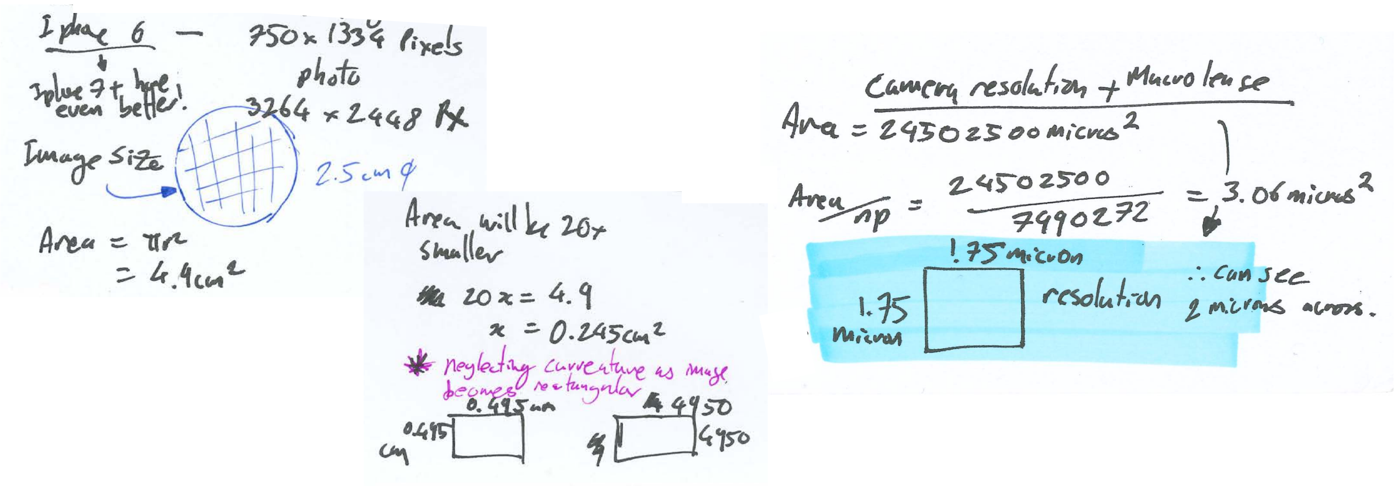
7 | Plastic Analysis Development

Although some of the target market such as schools will have access to simple microscopes that are able to magnify to the required 10x magnification used to identify the plastic it was important to find an alternative way to analyse, to make the process accessible to schools and environmental groups with less funding and financial resources. Multiple types of microscope where investigated such as the “foldascope” which was disregarded due to poor results and USB digital microscope which was disregarded due to the environmental and social impact of the electronic production (Tornbjerg.O, 2010). The microscope chosen to be added to a kit was a macro lens with x10 magnification that can be attached to any phone or tablet.

Due to high resolution of modern phone cameras it was found that the resolution needed to identify the plastic is well within range. iPhone 6 with resolution of 1334 x 750 pixels with the addition of the macron lens has the approximate resolution of 1.75x1.75-micron.

1.75^2 micron resolution

ability for macro-lens to enable the viewing of plastics



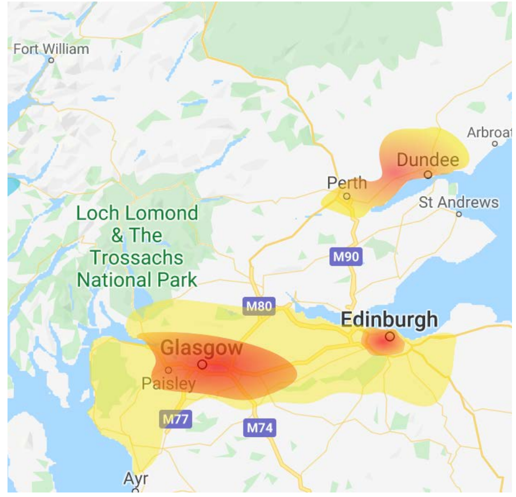
Once data is collected by the citizens it is added onto a data sharing platform. It was found in research stages that it is essential to understand, through comparison, the affect that human interference has on natural systems. It was also found that successful campaigns have a strong visual impact that can be quickly understood.

user interface needs

river comparison
clear communication
ease of use

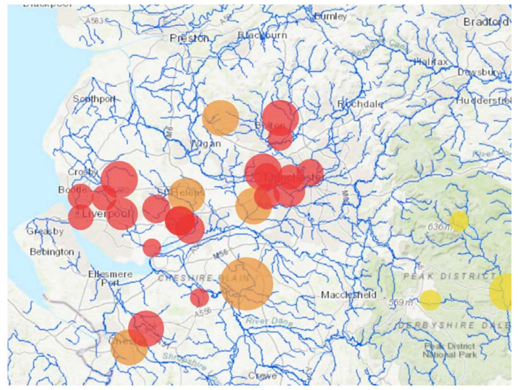
idea 1

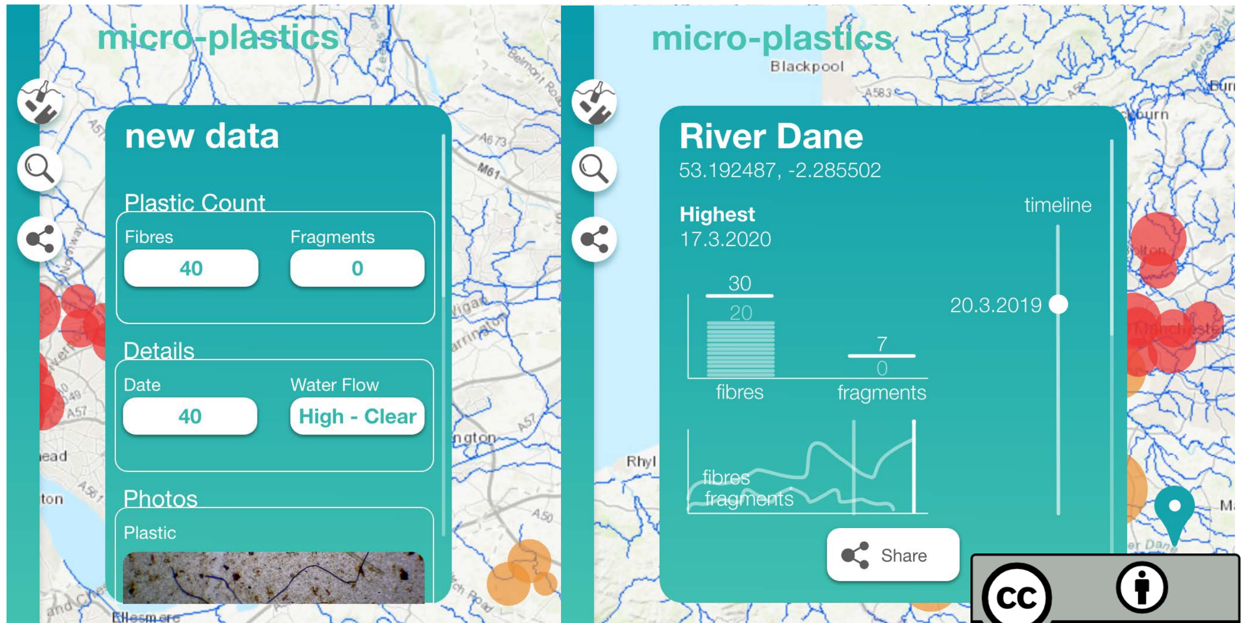
To ensure impactful visuals of the site the first design iteration pulled data points to create an average for the whole riverbed. This idea was however disregarded as full understanding and models of how plastic is transported and sedimented along the length of rivers would be required for the visual data to be accurate. This level of modelling is not available



idea 2

To rectify this colour coded spot data is used. The combination of these spots can give an overall indication of the area with increasing detail as the map in zoomed in, similar to the way details of photo locations appears on apples map gallery. This iteration also shifts the information hierarchy from roads to rivers.



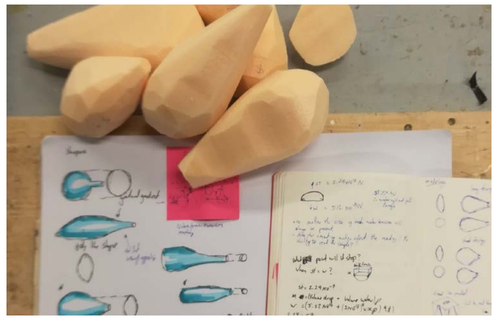


8 | Vessel Shape Development

For samples that truly reflect the abundance of plastics in rivers both in isolation and in comparison, the vessel needs to have minimal disturbance to flow as the water enters the inlet. The form of the vessel too has to have minimal disturbance so that the drag force (that users have to react against) is minimal.

$$F_{drag} = f(C_D, A, V, \rho)$$

It also needed to have a balance of visual communication of a scientific tool while being sensorily appealing - this led, through foam prototyping, to a tear drop shape with length of 1.5 times that of the maximum diameter and minimum radius 0.25 time that of the maximum diameter.



A maximum diameter for the vessel of 105mm was created from the "thumb to middle finger grip length" of the 5th percentile of the smallest of the target market – 12-year-old female. Due to the filtering paper chosen there is an associated time for the water to filter through – 70s/100ml. If the vessel was relatively large this would lead to extended periods to filter which could be longer than attention span of interest or cause muscular cause strain. Using this information, the time to filter was calculated for a range of proposed diameters - a diameter of 80mm was chosen for the final geometry of the vessel. This geometry was prototyped and taken to the Glasgow Science Centres "Curiosity Live" event where it was found that the ergonomics where suitable and received positive feedback.

A pivot point was added onto the design of the vessel to allow for air trapped within the vessel when submerged to be released and so that no water is lost when the vessel is being removed form the water. Multiple pivot points and methods where tested within the Hydrology lab.

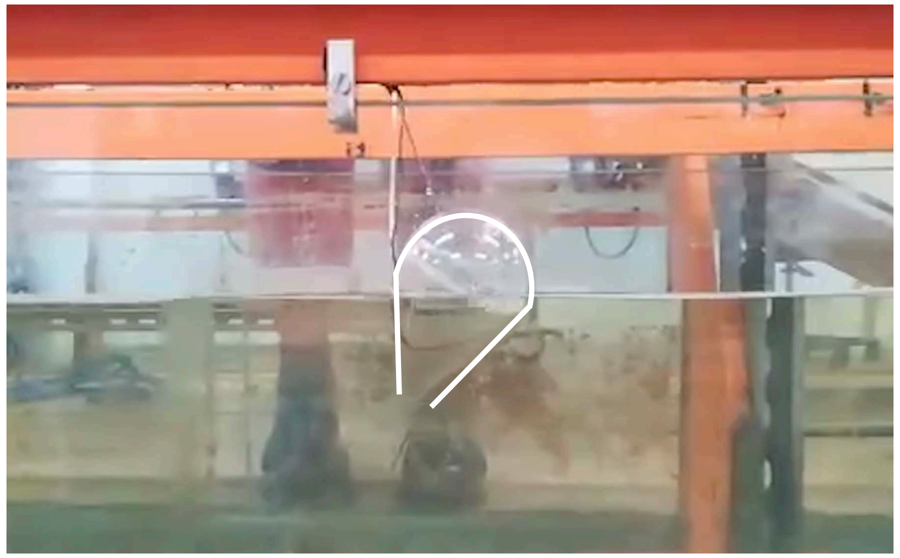
When the vessel is submerged the forces acting become equal when the volume of water and the volume of air are equal within the vessel. Due to the shape this means that if the pivot point is positioned in any point that is not the centre of mass of the vessel it will tip when the volume of air and water is not equal.

$$F_W = F_B$$

$$\rho_W V_W g = \rho_W V_A g$$

submerging

When the pivot point is positioned closer to the inlet than the centre of mass force is applied to submerge. This causes the vessel to rotate in the water and the inlet to point downward trapping considerable amounts of air.



surface

As the vessel fills the body sinks into the water causing it to rotate and tipping back and downward into the water. This method of testing on the surface also ensures that each sample is taken from the same point of the river column so was chosen for the design

9 | User Journey Development

Freshwater environments vary greatly both due to human and non-human influence and due to this so to do the citizen access points. It is essential that the kit can be used safely and does not pose risk to the younger target market. It was found that the access can be broken into bank and bridge deployment.

modular poles

bouy-bank

bouy-bridge

reeling rope

set-length pole

Different types of deploying were prototyped and experimented with at a local river. Due to the positive aspects of the tested mechanisms rather than the proposed dual functionality of a deploying mechanism this was split between the two types of access points, a pole used for bank and rope used for bridge access.

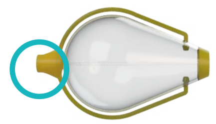
Due to the need for access to be safely performed it is essential that the bank attachment can be used without the risk of falling into the river. The minimum length of 953.2mm was created by analysing the user case of smallest grip height 674mm at a deploying angle of 45 degrees. Variety of lengths and handle designs were tested and an optimum length of 1m with a simple tapered top and rope holder was found.

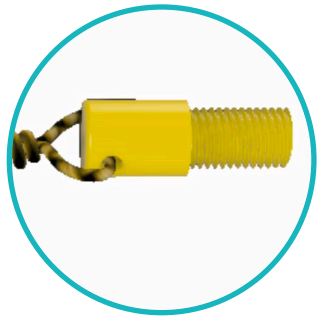
The material chosen for both the bank deploy and the rope holder within the bridge deploy is FSC certified pine due to the low carbon emission of the material and the simplicity of shapes allowing for CNC manufacture. To check the suitability of this the maximum deflection with the weight of the water was calculated to be 0.178e-10m suggesting the strength is more than adequate.

$$I = \frac{1}{4}mr^2 + \frac{1}{3}ml^2$$

$$MD = \frac{ml^2}{2EI}$$

Both deploying mechanisms are attached by twist as this is a fastening technique that cannot be easily replicated by the force of the water. Pivot has female threaded parts while attachments have male threading.

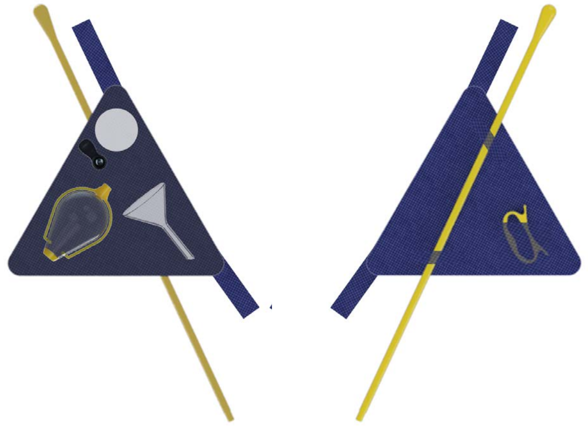


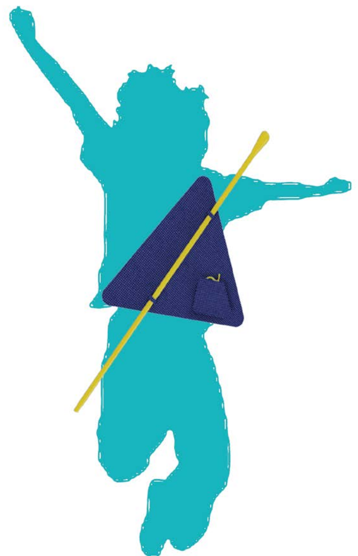


male threaded

female threaded

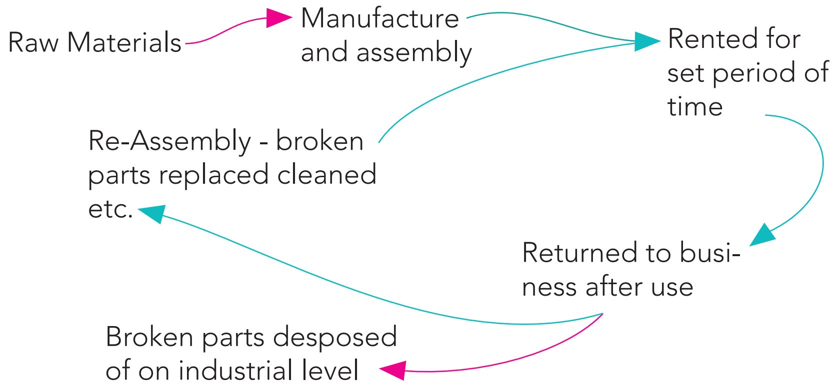
To make it possible to carry the kit to varying rivers a kit bag was designed. Each element has a specific pocket that is laid out in order of use to make the complex user journey easier to follow and to make it quick to check for missing components.





10 | Project Detailing

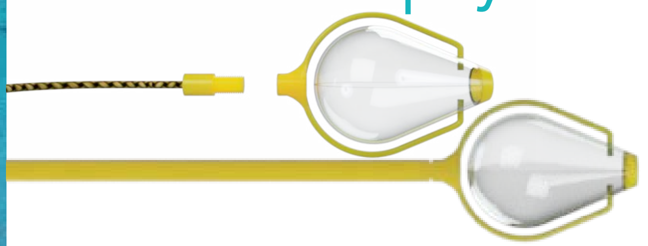
A rental business model was chosen as the high reuse of the kit in this model leads to the need for considerably less kits to be produced lowering the overall environmental impact. The repeated use of this kit lowers the retail price to the schools and groups making it more accessible in low income areas and smaller scale environmental groups while also allowing for more flexibility round material choice.



pivot & attachment

The selection of materials for the pivot and attachments faced a common environmental debate of the use of biopolymers against recycled plastic. Due to the high use of vastly varying virgin plastic and degradation of properties through recycling there is limited use of the vast quantities of recycled plastic in circulation. It is therefore argued that using material that is surplus has as better impact environmentally than the use of biopolymers that to have embedded energy. It was decided however that biopolymers would be used as the use of recycled plastics would most probably result in further microplastic pollution in the river environment.

coloured biopolymer



recycled plastic

pivot & attachment

After CES analysis and property comparison polyactide (PLA) manufactured using injection moulding was chosen for the pivot and attachments as it out of the selection had the best technical properties. In analysis it was found that the maximum deflection of the pivot is 4.16e-10m and the maximum pressure to be 0.29Mpa considerably lower than the yield strength of 55-72MPa.

$$I = \frac{1}{4}mr^2 + \frac{1}{3}ml^2$$

$$MD = \frac{ml^2}{2EI}$$

$$P = \frac{F}{A}$$

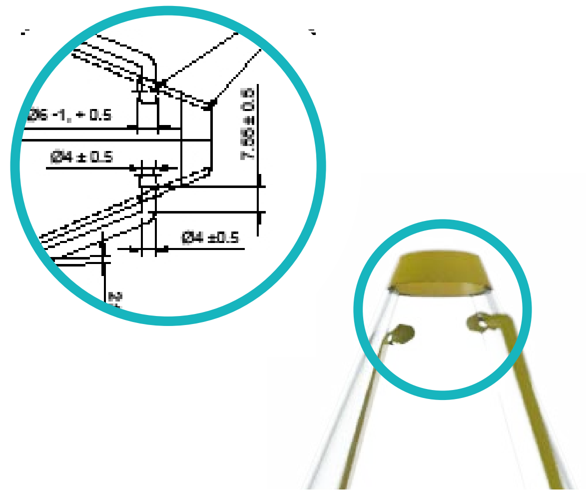
vessel

For the vessel to function it needed to be waterproof and transparent while supporting the weight of the water leading to the short-listing for consideration of glass and polylactide. As glass has low impact strength within the dynamic environment this could become a safety hazard so clear injection moulded polylactide was chosen.

The coloured ring used to alert when the vessel is full/tipped is polylactide based vegetable ink pad printed onto the vessel.

assembly

To assemble the pivot to the vessel a simple snap fit is used. To check that the force of the water is translated within the materials limits the stress was calculated assuming that 1/4 of the vessel is in contact with the pivot leg. This gave a stress of 0.1Mpa considerably lower than the yield strength of 55-72MPa.



3.43kg of Co2 | 1/3 of a t-shirt emissions

production cost per kit £45.18

£14.38 cost of rental 100 uses

Covid-19 had a considerable effect on the final progression of the project leaving prototyping and prototype testing with the proposed material and fixing details and testing impossible to carry out. Improvements to the product through further detailing and the campaign branding could have been done. Overall I am happy with the final design as it meets the difficult brief of sustainable design.

improvements

- full working prototype
- prototype testing
- user trials
- further detail