Business support – case study Aquacheck Engineering Ltd

Redesigning products with recycled plastic feedstock

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As part of the TRANSFORM-CE project, several case studies will be done to assess the conditions that foster the uptake of recycled plastic feedstock in (new) products. This document covers the results of the case study at Aquacheck Engineering Ltd, based in Rochdale, Lancashire, UK. A total of 20 case studies will be done, each representing one product to be (re)designed with recycled plastic. In depth support will be given to five cases per country (The Netherlands, Germany, Belgium, and the United Kingdom).

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1. Introduction and method

1.1 Goal of case study

TRANSFORM-CE is an international research project about the uptake of recycled single use plastic (SUP) feedstock. A core part of this project is to provide in-depth business support to businesses willing to use recycled plastic materials in (new) products. The uptake of SUPs implies that companies in the plastic industry must make a major transformation. In order to gain a better understanding of the support required for the wider uptake of recycled plastics (such as SUP) by companies, 20 different case studies will be completed, documenting the conditions that foster the uptake of recycled feedstock. In line with the technologies of the pilot plants from the TRANSFORM-CE project, cases will represent either IEM[1] technology or AM[2] technology.

Thus, the aim of these case studies is twofold; 1) to support the case study company with their specific request to help foster the uptake of recycled plastic feedstock into one of the company's products, and 2) to gather insights into the conditions necessary to support the wider uptake of recycled plastics by using IEM and AM technologies. The case studies also present a unique opportunity to study the technical requirements for (re)designing products with IEM and AM. The learnings of the various cases and (re)designed products could serve as a proof of concept that provides the entire value chain with the insight and confidence to uptake recycled feedstock, creating circular economy opportunities for all stakeholders.

1.2 Case study process

The case studies are being carried out between September 2021 and December 2022. The case study process is structured in four steps[3], with an iterative approach at the end of each step. The first step (*initial diagnostic*) aims to establish a starting point and describes the challenge to be addressed. The second step (*circular product development*) captures basic information about the product (re)design and describes prototyping and testing leveraging IEM and/or AM technologies. The third step (*circular product management*) covers how to commercialise the new (or redesigned) product and describes the product's relevance for business and environment, creating a successful circular business model. The last step involves a wrap-up of the results and concludes with strengths of the redefined business model, an overview of the barriers and enablers for circularity, and learned lessons from the case study. The final result is a case study report, covering the previously established information.

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[1] IEM: Intrusion-Extrusion Moulding (for low(er) value recycled material), a combination of two techniques to produce plastic products/components. With extrusion the polymer is being melted, thereafter the polymer is being forced into a shape (by using a mould).

[2] AM: Additive Manufacturing (for high(er) value recycled material), method of creating objects layer by layer according to a digital design.

[3] This work uses insights derived from other activities of TRANSFORM-CE, in particular the case study method of WPT3 D2.1: *Case study methodology - Researching good practices of circular economy business models.*

The total case study can be seen as a package of business support (all steps). Yet, a specific type of 'in-depth support', chosen from the menu-card[4], will be done for each case study. This support differs from company to company and will be selected based on a first analysis of the case. Examples of in-depth support include: material testing, prototyping and production trials, implementation of technology and use of recycled filament.

An overview of the case study analysis process is shown in figure 1 on the next page. In order to obtain the results, a 'collaborative/participative' assessment is used to collect further information, which gives insights in the overall innovation process. At the end of the case study, an iteration will be done to validate the results. The reported results will be send to the contact person by email, so this person can validate the results and check if something is still missing or if information has been misinterpreted. Any comments will be processed and the results will be adjusted accordingly. Table 1 gives an overview of the people that have been interviewed during the case study.

Table 1: *Overview of interviewed people*

	Interviewed person	Function
Step 1: Initial diagnostic	Paul Carrington	Owner
Step 2: Circular product development	Paul Carrington	Owner
Step 3: Circular product management	Paul Carrington	Owner

[4] An extensive list of the support possibilities is presented in a separate document '*Transform-CE support Summary*', describing the menu-card.

Step 1. Initial Diagnostic

- First assessment of company
- Establish starting point
- Describe challenge to be addressed
- State project goal

Step 2. Circular Product Development

- Describe product to be (re)designed
- Assess context in which product will be produced, used and marketed
- Design product
- Describe product's relevance for business and environment
- Create successful circular business model
- Prototyping and testing leveraging IEM and/or AM technologies

Step 3. Conclusion

- Wrap-up of results
- Strengths of redefined business model
- Summarise barriers and enablers for circularity
- Describe learned lessons

Report

- Succinct, yet informative case study report
- Excellent exposure opportunities for business

Figure 1: *Overview of case study process*

2. Step 1 – Initial diagnostic

The first step focusses on an initial diagnostic of the case study, which includes outlining the company profile, its wishes, and the project goal.

2.1 Company profile

Aquacheck Engineering Ltd is an engineering SME, based in Rochdale, Lancashire which focuses on providing innovative solutions to the water industry. A short overview of Aquacheck Engineering Ltd is given in table 2.**Error! Reference source not found.**

Table 2: *Overview of company*

Topic	Information
Company name	Aquacheck Engineering Ltd
Website	https://aqua-check.co.uk/
Country	UK
Size of company (0-10, 10-200, 200-500, 500+ employees)	10-200
Mission/vision	Transforming from an engineering company to a provider of innovative R&D within the water industry, bringing innovations to the forefront.
Value proposition	Established as a “nuts and bolts” engineering company in the water industry, with main activities including the supply of hoses, brass valves couplings and leak detection kits. The company is currently experiencing a transition in its proposition, where it is moving towards the provision of more innovative solutions. Aquacheck Engineering Ltd supplies water companies on an international scale, with a large proportion of their intended client base situated in the UK and USA. They have also partnered with research, academic and industrial partners, to explore new innovative solutions.
Main activity	Manufacturer of WRAS approved valves, pipes, and tools for the water industry. Development and manufacture of innovative R&D smart meter technology which allows suppliers to remotely monitor water usage.

2.2 Current situation & challenge

Aquacheck Engineering Ltd was established as a “nuts and bolts” engineering company in the water industry, with main activities including the supply of hoses, brass valves couplings and leak detection kits. The company is currently experiencing a transition in the services it provides, where it is moving towards the delivery of more innovative solutions that will address the challenges faced by the water industry. Barriers to this transition has included the availability of in-house capacity, funding and/or expertise.

To invest in the future of the company, Aquacheck Engineering Ltd has collaborated with research, academic and industrial partners to explore new innovative solutions. The result of which has seen Aquacheck Engineering Ltd become a front runner of innovative R&D within the water industry. Previous collaborations have seen the development of smart meter technology that allows water companies to remotely monitor water usage.

Building on the smart meter technology, Aquacheck Engineering Ltd wish to develop further sensors that can monitor levels of lead (Pb) present in the water. Elevated levels of Pb (which is harmful for environmental and human health) have been identified in water supplies globally, especially where the supply infrastructure uses lead pipes, lead solder and/or brass valves. Traditional methods of sampling water can be limited (and expensive) due to the time and expertise required, resulting in disparate sampling across networks.

Aquacheck Engineering Ltd would like to develop a simple sensor that could be used (with little/no training) at the tap, and provide Pb readings via an app. As this could negate the time and expertise required by traditional methods, Aquacheck Engineering Ltd are hoping to significantly reduce the cost of each sample, meaning that more samples can be undertaken in the same time frame. This saturation of samples across a water companies' network could help identified hotspots, from which the water company would then be able to focus their remedial/replacement works on targeted areas.

Description of support

The support provided to Aquacheck Engineering Ltd has centred around the development of 3D-printed conductive filaments to monitor levels of Pb within a sample of water, as well as the design and prototyping of a sampling unit.

3. Step 2 – Circular product development

After creating a first analysis of the company and project, a more detailed assessment of the (re)designed product is made. This includes basic information about the product and an assessment of the context in which the product will be produced and used, as well as an analysis of the circularity of the product. Moreover, a more detailed design of the product is created, which goes hand in hand with prototyping & testing.

3.1 Circular product canvas

The new (or redesigned) product is investigated by using a circular product canvas (CPC). This model is created for the purpose of this study and covers the main aspects to consider in circular product design. The CPC of Aquacheck Engineering Ltd is visible in Figure 2 and a description of each element is given below.

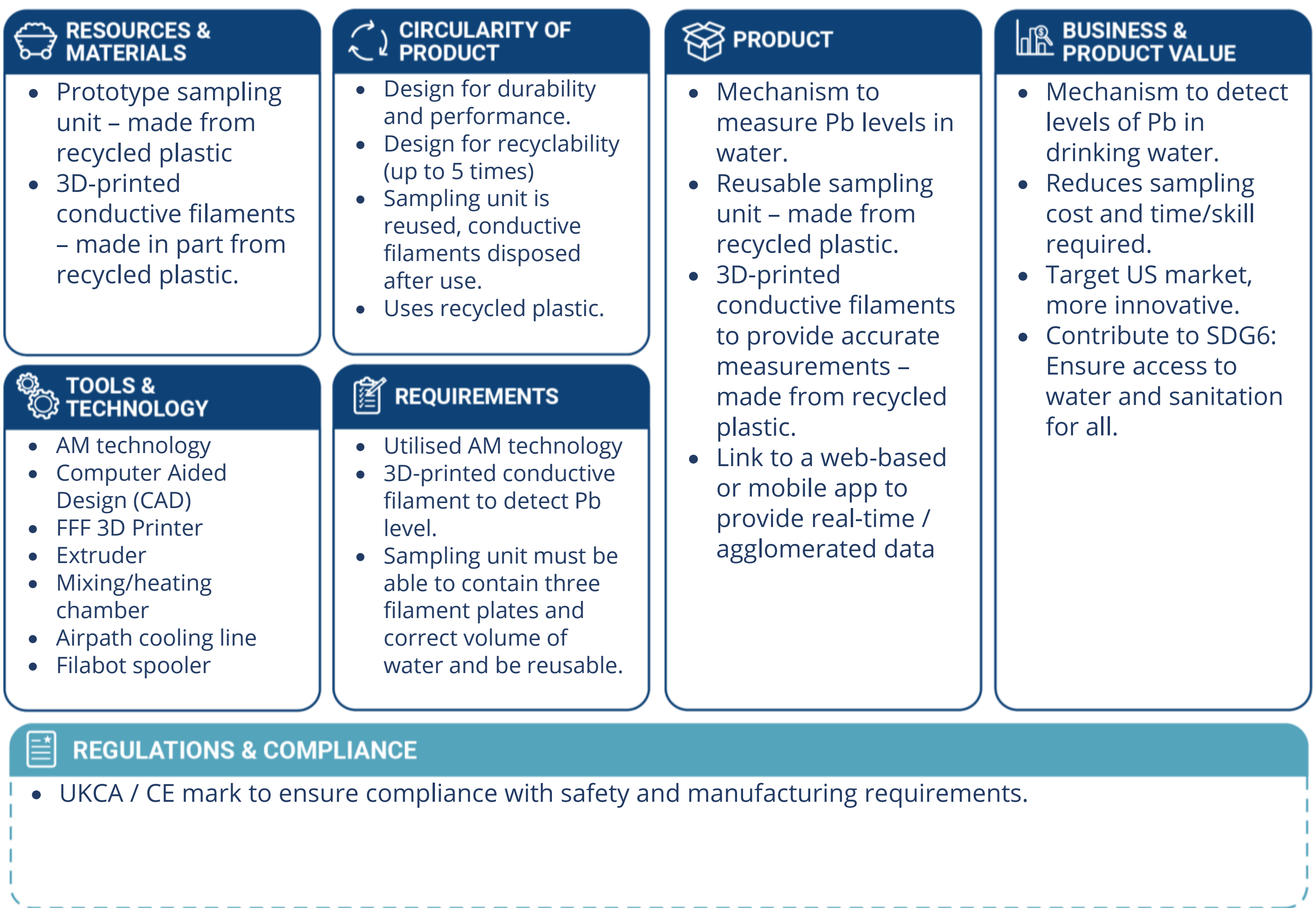

Figure 2: *CPC of 3D-printed conductive filaments and sampling unit for Aquacheck Engineering Ltd*

Product

The product have been developed to provide a mechanism by which the levels of Pb in drinking water can be easily monitored. Through its innovative design, it is thought that the product could negate the time and expertise required by traditional methods to undertake a scheme of water samples.

The product includes a sampling unit, which can be used to collect a pre-determined quantity of water straight from the tap. The sampling unit will be made from recycled plastic and can be reused multiple times.

To measure levels of Pb in each water sample, 3D-printed conductive filaments have been developed to provide concentration readings. The 3D-printed conductive filaments will also utilize recycled plastic but will be discarded after each reading. The reading provided by the 3D-printed conductive filaments will eventually link up to a web-based or mobile app to provide real-time or agglomerated data.

Resources & materials

Both the 3D-printed conductive filaments and the sampling units were made (at least in part) with recycled plastic. The former also contains a minor conductive component, in this case carbon black and was compounded using a plasticizer. The prototype sampling unit was produced using recycled PLA filament supplied by the Transform-CE project.

Tools & technology

During the development of the 3D-printed conductive filaments, Computer-Aided Design (CAD) and AM technologies were used. Object design is completed using CAD software, which is then digitally "sliced" into pseudo-2D layers, and finally sent to a 3D printer to be built. Production of parts in this way has a number of advantages, for example, the ability to manufacture locally and on-demand, plus it affords a high degree of part complexity and easy customization of objects. (Wuamprkhon *et al.*, 2022). This provides a certain level of agility to improve the design of the filaments between iterations, and allows the support team to incorporate feedback from Aquacheck Engineering Ltd.

Preparation of the 3D-printed conductive filament required,

- a mixing/heating chamber: the Thermo Haake Poydrive dynameter fitted with a Thermo Haake Rheomix 600 (Thermo-Haake, Germany),
- use of a granulator: the Rapid Granulator 1528 (Rapid, Sweden),
- use of an extruder: the EX6 extrusion line (Filabot, VA, USA),
- and the use of an Airpath cooling line and spooler (both Filabot, VA, USA).

In addition, the design and prototyping of the sampling unit also utilised CAD and AM technologies, where the final prototype was printed using recycled PLA filament sourced from the Transform-CE project.

Circularity of the product

The design and development of the sampling unit and 3D-printed conductive filament was optimised for durability and performance respectively. The intention is for the sampling to be used multiple times and has been designed so that it can be recycled up to 5 times (simple design, mono-material, no adhesives, or connectors). The 3D-printed conductive filament on the other hand, is designed to be discarded after every use, but is optimised with respect to its performance, in this case sensitivity when measuring Pb concentrations in water samples. It is intended that the final product will utilise recycled material in production, with the prototypes printed using Transform-CE recycled PLA filament.

In the context of the broader system, a key element of this product that contributes to circularity is the ability to overcome issues related to traditional methods of sampling water (which can be limited (and expensive) due to the time and expertise required). The use of this product could overcome the resultant disparity in sampling across networks (which is a feature of current sampling methods) by significantly reducing the cost and time required to undertake each sample, meaning that more samples can be tested within the same time frame. This saturation of samples across a water companies' network could help identified hotspots. From which the water company would then be able to focus their remedial/replacement works on targeted areas, thus making savings in terms of energy, resource, and labour costs.

Requirements

The development, design and prototyping of the final product has been completed using AM technology. The prototype was printed using recycled plastics and utilised the recycled filament from the Transform-CE project.

In terms of technical requirements, the 3D-printed conductive filaments should be developed to enable the measurement of Pb concentrations from a sample of water. Furthermore, the sensitivity of the 3D-printed conductive filaments should be determined to access accuracy and precision.

The design of the sampling unit should incorporate the use of recycled plastic, be durable enough to enable reuse across multiple sampling points, accommodate the three 3D-printed conductive filament plates, and be able to contain an appropriate volume of water to enable a sufficient reading. The inclusion of a "fill to" line in the design will help user to collect the correct amount of water to enable the test to be completed successfully.

Business and product value

This product has been developed in order to provide a mechanism by which the levels of Pb in drinking water can be easily monitored.

Aquacheck Engineering Ltd are hoping to significantly reduce the cost of each sample, meaning that more samples can be undertaken in the same time frame. This saturation of samples across a water companies' network could help identified hotspots, from which the water company would then be able to focus their remedial/replacement works on targeted areas.

While Aquacheck Engineering Ltd would initially promote the concept and product in the UK (which has 23 distinct water companies), they have ambitions to target the US market which is more forward thinking when it comes to innovations and contains thousands of individual water companies.

As well as an innovative design, this product uses recycled materials, encourages the reuse of the sampling unit, and could help to save time, energy, and resources. The use of the product could also contribute to SDG 6: Ensure access to water and sanitation for all (UN General Assembly, 2015), especially when used in less developed countries, and in countries who still rely on older water infrastructure such as the use of lead pipes, lead solder and/or brass valves.

Regulations and compliance

Currently any product sold in the UK and Europe must adhere with UKCA / CE requirements, respectively. In technical terms, the differences between the requirements for CE marking and for UKCA marking are slight. Products which meet the technical requirements for one will mostly meet the requirements for the other for the foreseeable future. Most of the differences between the two systems are administrative in nature and reflect the fact that the UKCA mark only applies in Great Britain (England, Scotland, and Wales only, products sold in Northern Ireland must conform with CE marking).

3.2 Design, prototyping & testing

The support provided to Aquacheck Engineering Ltd centred around the development of 3D-printed conductive filaments (as proof of concept) to measure levels of Pb in drinking water, alongside the design and prototyping of a sampling unit. AM technologies have been utilised in this casestudy.

The 3D printed conductive filaments were developed to monitor levels of Pb within a sample of water. Conductive filament is an emerging material type that's great for small DIY electronic projects or small circuits. Conductive means that electricity can flow through it, hence the filament's usefulness in projects like key fobs, LED gloves, and even auto-bed levelling sensors. Conductive filaments are made from plastic (commonly, PLA or ABS) and a conductive media, such as graphene or carbon black.

Bespoke part production, delivered by AM technologies, is becoming increasingly popular in the fields of electrochemistry, electrochemical equipment, electroanalysis, and reaction mechanistic studies. Where an increasing number of studies have detailed the use of FFF 3D printers to produce inventively designed fixtures, sample holders, and even electrodes when a conductive polymer composite material is used. Producing electrochemical components by AM is not only convenient and cheap but also can afford electrode architectures not normally accessible by traditional techniques (Wuamprkhon *et al*., 2022).

In this proof-of-concept study, the novel utilisation of recycled plastic was employed to create a conductive filament that is highly printable and can be effectively used to measure levels of Pb in a sample of water. Production of the conductive filaments was modified from the method reported by Wuamprkhon *et al* (2022). The developed conductive filaments were tested at various Pb concentrations to ensure appropriate sensitivity. Testing was completed through a rigorous and in-lab scheme of works, which allowed for re-iteration in the design/production of the conductive filament.

Finding from these tests indicate that the 3D-printed conductive filament can identify Pb at concentrations of 5ppb (or µg/L), within a sample of water. In the UK, the Department of Health set the standards for safe drinking water (including both public and private supplies), where it is currently set to allow no more than 10ppb (or µg/L) to be present (UK GOV, 2016 a, b). This suggests that the 3D-printed conductive filaments developed by MMU has the sensitively necessary to measure the levels of Pb in water to an appropriate accuracy/precision. This therefore provides proof of concept.

A simple geometric design for the sampling unit was designed using CAD software. As shown by Figure 3, the sampling unit was design to hold three testing plates (made from 3D-Printed conductive filament) in place, and to collect (and hold) a suitable quantity of water to test. A “fill-to” line was included in the design of the sampling unit to indicate how much water is required for the test to be completed correctly. Prototyping of the sampling units was completed using TRANSFORM-CE recycled filaments, produced using a FFF 3D printer.

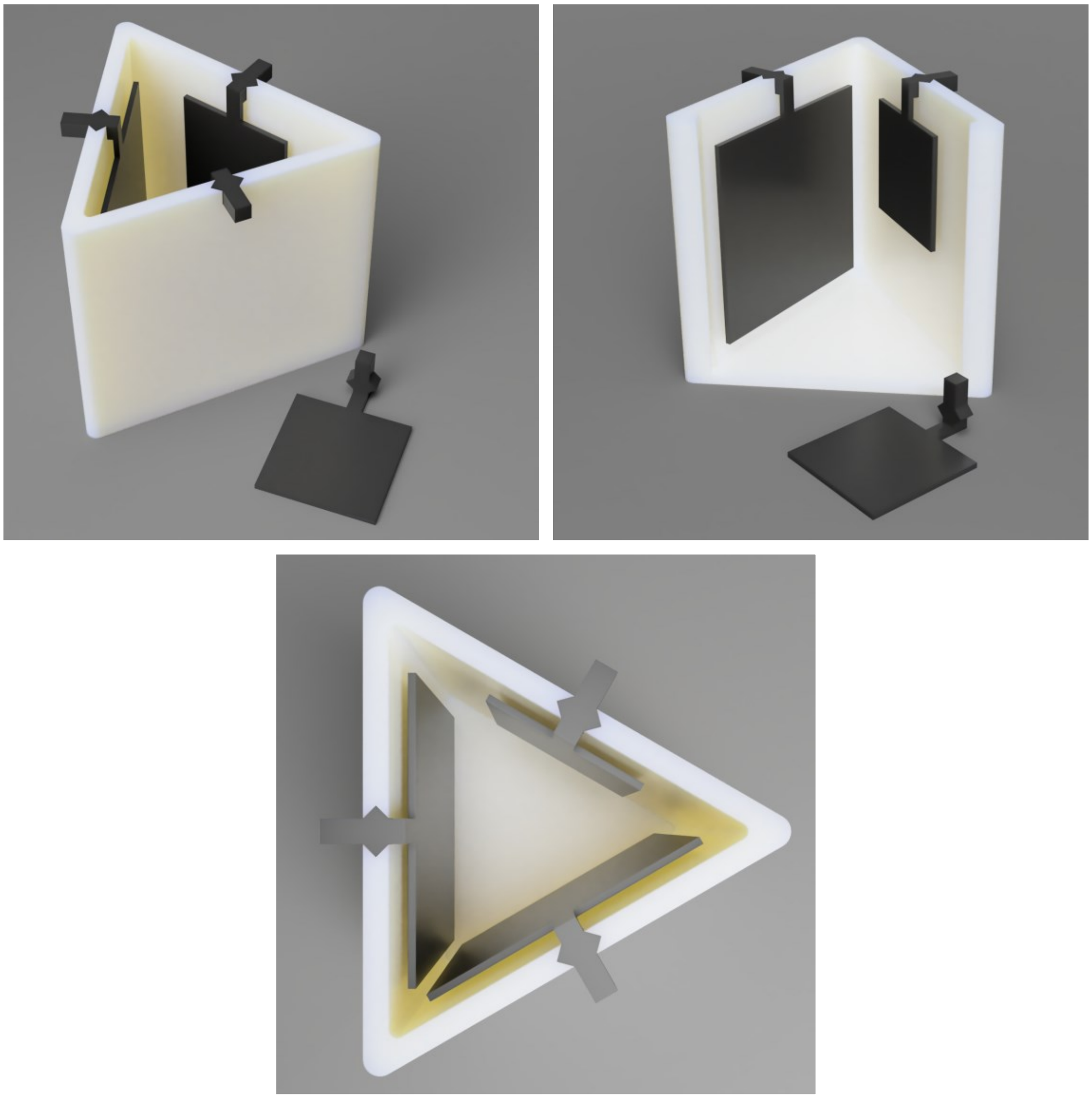

Figure 3: *Render designs of the 3D-printed conductive filaments and the prototype sampling unit.*

4. Step 3 – Conclusion and recommendations

After going through the previously described steps, a wrap-up is presented in this chapter. This includes identifying the strengths of the redefined business model in regard to circularity, describing the learned lessons from the case study project and providing recommendations for the next steps.

4.1 Strengths of the redefined business model

Circularity of the product

The design and development of the sampling unit and 3D-printed conductive filament was optimised for durability and performance respectively. The intention is for the sampling to be used multiple times and has been designed so that it can be recycled up to 5 times (simple design, mono-material, no adhesives, or connectors). The 3D-printed conductive filament on the other hand, is designed to be discarded after every use, but is optimised with respect to its performance, in this case sensitivity when measuring Pb concentrations in water samples. It is intended that the final product will utilise recycled material in production, with the prototypes printed using Transform-CE recycled PLA filament.

In the context of the broader system, a key element of this product that contributes to circularity is the ability to overcome issues related to traditional methods of sampling water (which can be limited (and expensive) due to the time and expertise required). The use of this product could overcome the resultant disparity in sampling across networks (which is a feature of current sampling methods) by significantly reducing the cost and time required to undertake each sample, meaning that more samples can be tested within the same time frame. This saturation of samples across a water companies' network could help identified hotspots. From which the water company would then be able to focus their remedial/replacement works on targeted areas, thus making savings in terms of energy, resource, and labour costs.

Furthermore, the product itself is cheap, easy to use (no specialist knowledge or experience required to conduct a reading) and very portable. As such it could be used in less developed areas and in countries where existing waste infrastructure relies on old lead pipes. By monitoring Pb levels in drinking water, hotspots that require immediate attention could be highlighted, thus contributing to SDG 6: Ensure access to water and sanitation for all (UN General Assembly, 2015).

Product (re)design, testing and/or prototyping

The supported offered by MMU was to develop an easy-to-use mechanism by which concentrations of Pb could be measured in-situ. AM technology was used in the design, development, and prototyping of the product, further laboratory testing was also employed.

Specifically, the support provided centred around the development of 3D-printed conductive filaments (as a means to measure Pb concentrations) and the design / prototyping of a sampling unit. The developed conductive filaments were tested at various Pb concentrations to ensure appropriate sensitivity. Prototyping of the sampling units have been completed using TRANSFORM-CE recycled filaments.

4.2 Lessons learned

The support provided has delivered proof of concept and product prototyping. This case study has highlighted the agility and speed at which AM technologies can be used to design, develop, and prototype products.

4.3 What's next

Next steps (beyond the scope of TRANSFORMS-CE) will be to support the company in upscaling the product so that it is ready to take to the market. This will include the development and integration of a web-based or mobile app, which would be used to receive real-time or agglomerated data from the sampling unit.

References

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UK GOV (2016b) The Private Water Supplies (England) Regulations 2016

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About the project

The problems associated with plastic waste and in particular its adverse impacts on the environment are gaining importance and attention in politics, economics, science and the media. Although plastic is widely used and millions of plastic products are manufactured each year, only 30% of total plastic waste is collected for recycling. Since demand for plastic is expected to increase in the coming years, whilst resources are further depleted, it is important to utilise plastic waste in a resourceful way.

TRANSFORM-CE aims to convert single-use plastic waste into valuable new products. The project intends to divert an estimated 2,580 tonnes of plastic between 2020 and 2023. Two innovative technologies – intrusion-extrusion moulding (IEM) and additive manufacturing (AM) – will be used to turn plastic waste into recycled feedstock and new products. To support this, an R&D Centre (UK) and Prototyping Unit (BE) have been set up to develop and scale the production of recycled filaments for AM, whilst an Intrusion-Extrusion Moulding Facility, the Green Plastic Factory, has been established in the NL to expand the range of products manufactured using IEM.

Moreover, the project will help to increase the adoption of technology and uptake of recycled feedstock by businesses. This will be promoted through research into the current and future supply of single-use plastic waste from municipal sources, technical information on the materials and recycling processes, and circular business models. In-depth support will also be provided to a range of businesses across North-West Europe, whilst the insights generated through TRANSFORM-CE will be consolidated into an EU Plastic Circular Economy Roadmap to provide wider businesses with the 'know-how' necessary to replicate and up-scale the developed solutions.

Lead partner organisation
Manchester Metropolitan University

Partner organisations
Materia Nova
Social Environmental and Economic Solutions (SOENECS) Ltd
Gemeente Almere
Save Plastics
Technische Universiteit Delft
Hogeschool Utrecht
Hochschule Trier Umwelt-Campus Birkenfeld Institut für angewandtes Stoffstrommanagement (IfaS)
bCircular GmbH

Countries
UK | BE | NL | DE

Timeline
2019-2023

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