The Sustainability of 3D Printing & Microfluidics in Pharmaceutical Manufacturing

Lamprou Lab
Emerging Technologies

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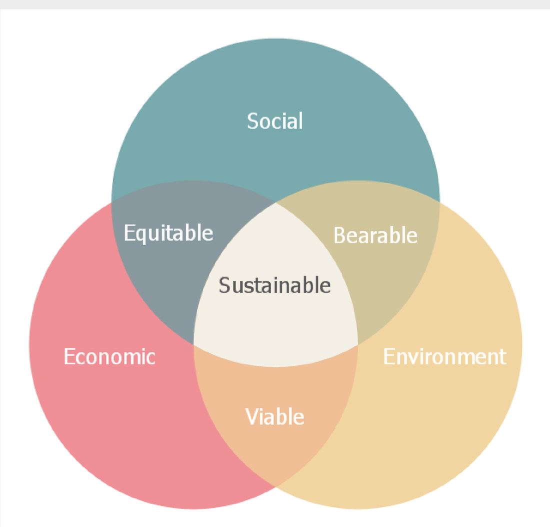
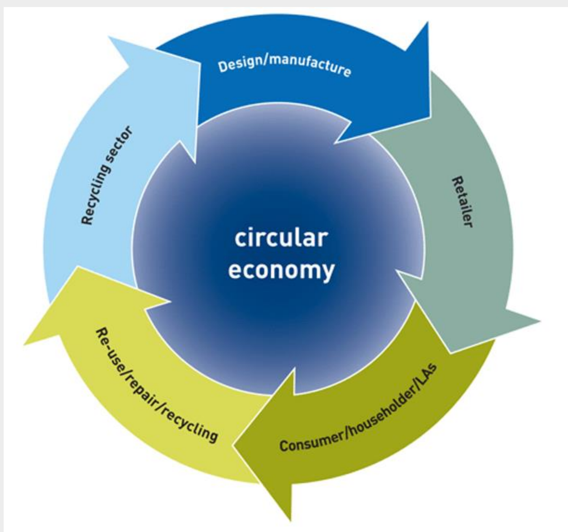
Background

The global acceptance of human driven climate change has reframed the future priorities of many industries. The pharmaceutical industry is not immune from either the concerns or innovations that are born from the attempts to address this emergency.

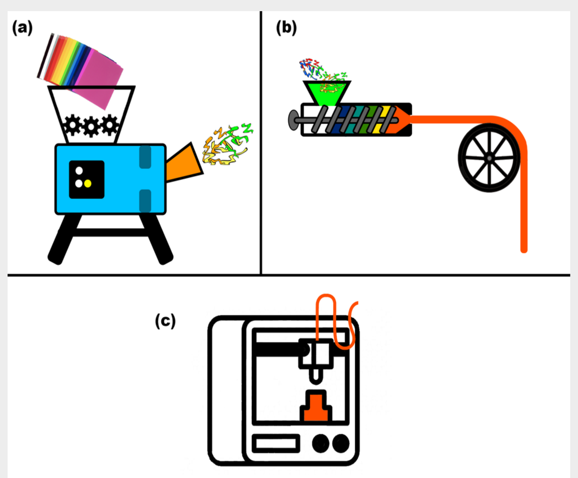
The importance of 'sustainability' has been recognised throughout many industries, resulting in frameworks being developed to ensure sustainable practice is realised. Further, the concept of a 'circular economy' should be considered in all stages of production and manufacturing 'from cradle to grave'.





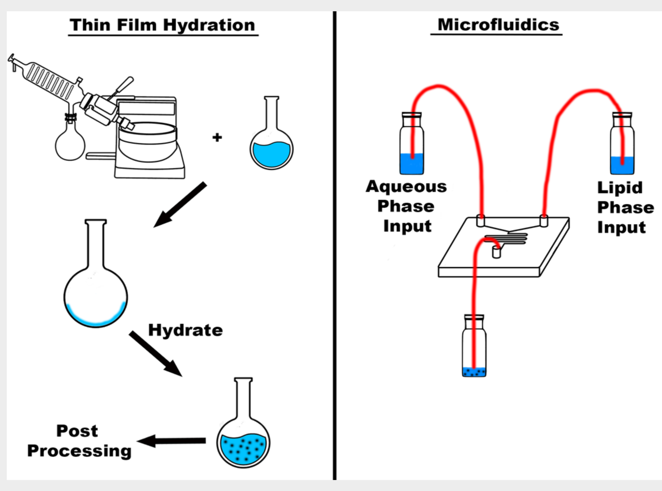
The pharmaceutical manufacturing industry is responsible for 52Million tCO2e – less than the automotive industry [1].

Additive manufacturing (AM) and microfluidics (MF) use in pharmaceutics are quickly becoming some of the most innovative and accessible technologies available. The sustainability of these emerging technologies could play an important role in the overall global impact of the pharmaceutical industry.



As of 2021, it is estimated that 16.4% of revenue collected from AM processes was related to medical implementation via 3D printing (3DP) [2].

MFs show great promise in a variety of fields such as nanoformulation and compound separation. The chips can be manufactured in a variety of ways, including via 3DP.



Methods

The sustainability potential of AM and MF, and what impact this could have on the wider pharmaceutical industry have been assessed. This has been conducted using a PESTLE analysis where political, economic, social, technological, legal and environmental factors are scrutinised. The impact of PESTLE factors are displayed for the pharmaceutical industry as a whole, then further narrowed down towards 3DP and MFs.

Following this, each emerging technology is considered in comparison with its traditional counterpart. This includes an overview of typical CO2 emissions, its role within a circular economy and its accessibility for use in pharmaceutical manufacturing.

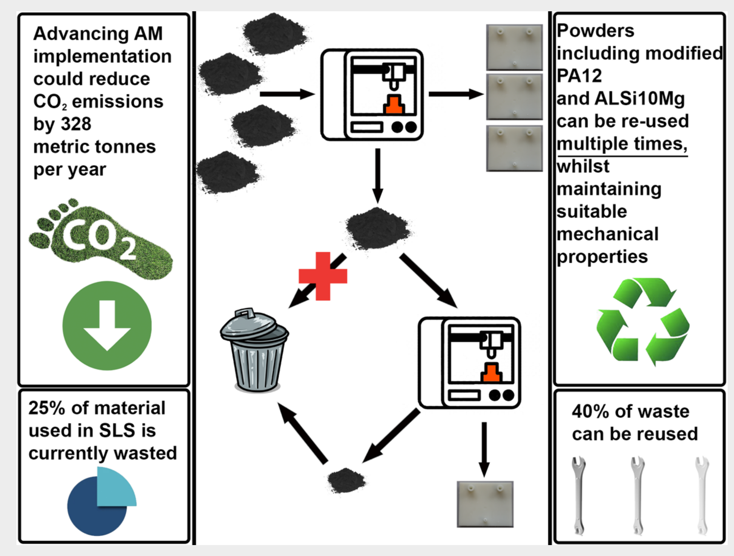
Results – PESTLE Analysis

	Pharmaceutical Industry	3DP	MFs
Political	Global governments have a close focus on healthcare and pharmaceuticals in the wake of Covid-19 pandemic, mostly in a positive manner.	Government support for this emerging technology can be seen globally with recent examples such as the UK government's Technology Strategy Board 'Innovate UK' granting over £650,000 to a project seeking to produce 3D printed medicines in 2019.	There is currently not a large political influence governing the hinderance or progress of MFs.
Economic	Although GDP has suffered in many companies worldwide due to impacts of the Covid-19 pandemic, the pharmaceutical industry has experienced a renewed focus on research and development funding. The pharmaceutical manufacturing industry as a whole is expected to grow at a compound annual growth rate (CAGR) of 11.34% from 2021 to 2028	Traditional mass production techniques are likely to remain cost-effective, therefore could be the preferred manufacturing technology for years to come. Now at a stage of development that requires mass buy-in from key stakeholders such as manufacturing partners and clinicians.	One of the foremost pharmaceutical markets which continues to have wide-spread attraction in funding and research. The global MFs market is projected to grow at a CAGR of 17.5% from 2022 to 2027 with the MF chip segment driving this growth.
Social	Rising awareness of health and wellbeing amongst the global population. Aging global population.	Allows for a more personalised treatment pathway for service users potentially within a shorter time frame, thus improving overall patient experience.	The ease of use of MF devices as well as their small footprint allowing for portability, makes this technology ideal for point-of-care use.
Technological	The age of the internet and social media has allowed for improved communication streams from industry/researcher to end user, allowing for direct marketing and data collection.	Use of 3DP provides time saving benefits in the early drug development phase. Recent developments have allowed for readily available 3DP technologies which are capable of advanced techniques.	Although not a new technology, MFs is still in the research and development stage. However, as 3DP technology becomes more readily available it is expected that this will allow for faster, cheaper, and more easily customisable MF developments in the immediate future.
Legal	Robust legislation exists globally for manufactured medical production and pharmaceutical research (FDA in US, EMA in EU).	Legislative issues arise where 3DP pharmaceutical research advances at a faster pace than is legally manageable. This is a prominent concern in the use of bioprinting. Whilst legislation exists for research and manufacturing, one of the advantages of using 3DP in healthcare (small scale treatment personalisation) is so novel that legislation for this end use is sparse.	Despite the potential of MF, there are no standards or regulations specific to the industry.
Environmental	Pollution events increasing globally leading to increased health impacts for local populations. As experienced globally in 2019/2020, the risk of global financial/societal collapse should not be underestimated.	As 3DP becomes more widely applicable for drug delivery systems, medicines can be more personalised thus reducing the need for large scale manufacturing. The high use of polymers in 3DP poses questions regarding the technology's position in the waste hierarchy and wider circular economy.	MF use in environmental sciences and engineering is growing due to the many advantages they have for that industry. Decrease in material usage, especially during formulation is seen as a huge advantage for this technology.

Results - Sustainability

AM

Manufacturing Method	Manufacturing Name	Compatible Materials	Typical CO_2 Emissions (kg per parts)	Uses for Pharmaceutical Manufacturing
AM	SLS	• Thermoplastic Polymers • Laser-insensitive APIs	0.084	Wound dressings Prosthetics Surgical models
	SLA	• Ceramics • Acrylate-based resins	0.029	• Bio-implants • Preoperative models • Oral dosage forms
	Fused deposition modelling (FDM)	• Thermoplastic polymers Polymer-matrix composites	1.22	• Tablet manufacturing • Medical implants • Tissue scaffolding
	Selective laser melting (SLM)	Metal alloys Silicon carbide	13.15	• Medical implants
Traditional	Casting	• Various Metals • Resins • Rubbers	4.3	• Surgical tool and medical device manufacture
	Injection Moulding	• Thermoplastics • Metals • Glasses	0.003	• Tablet manufacturing



MF

- One of the most promising emerging branches of MFs appears in the study of paper MFs.
- Paper MF devices come from a renewable source, are transportable, don't require external power sources and are widely recyclable.
- The capacity for these devices to provide point-of-care testing (POCT) reduces the need for samples to be sent away for further analysis, reducing the carbon footprint of the overall process

Discussion

- Both the emerging technologies discussed represent a significant progression in improving the impact that the pharmaceutical industry is having worldwide.
- The research and competition in AM is resulting in faster, cheaper, and more environmentally friendly results
- The reduction of materials used during the process, and its subsequent reduction in wastage, has solidified MFs as a desirable pharmaceutical method for future investment

References

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[2] Devi, A., K. Mathiyazhagan, and H. Kumar, *Additive Manufacturing in Supply Chain Management: A Systematic Review*. 2021, Springer Singapore. p. 455-464.