



Technical Note:

Glass vs Single Use Plastics: Advantages and Disadvantages of Each Technology

Introduction

The increased adoption of single use plastic technologies for all aspects of laboratory work has brought benefits in terms of reduced preparation time, elimination of cleaning and autoclaving cycles, and a corresponding reduction in utilities costs. As many countries, pharmaceutical companies and leading research and teaching establishments are adopting more stringent environmental and sustainability standards, the dependence on single use plastics is being reviewed, questioned and evaluation programs are being proposed to look at alternative, affordable but more sustainable methodologies.

In an ideal situation all plastic waste would be recycled, however multiple studies (1, 2, 3, 4) have shown that less than 14% of all global plastic waste is sent to recycling, of which only about half is successfully recycled. The remainder goes to landfill (47%), incineration (17%) and the remaining 22% is mismanaged or ends up as uncollected litter.

Plastics that are used in biological research applications, such as cell and tissue culture, recycling presents significant challenges because of the often-multiple different plastics used in a single device, and the contamination of the device by potentially harmful biological materials. Sterilization and depyrogenation by autoclaving is the best solution, some plastics (polypropylene and polycarbonate) are autoclavable and can be reused, but will eventually be disposed of, not recycled. The majority of plastics have a melting point that cannot withstand the temperatures required for successful sterilization and depyrogenation, therefore reuse is not an option. This leaves chemical decontamination as the only option, which then requires efficient rinsing of the plastics, followed by safe disposal of both the decontamination solution, the rinse solutions and the plastic itself.

Before plastic consumables became the standard process in tissue and cell culture applications, glassware was routinely sterilized, depyrogenated and reused (7). Reintroducing the use of glassware holds the potential to significantly reduce both plastic waste and CO₂ emissions and may be one step towards achieving the climate neutrality goals set by the European Commission for 2050 (5). Proposals (6) have been made that promote the routine cleaning and reuse of plastic components to reduce waste and promote sustainability. While this is a solid strategy where potential cross contamination issues do not exist, or biological waste remediation is not an issue, in many laboratory environments it is not an applicable solution to reducing waste

Note

In this comparison the terms below are defined as:

- Rigid walled plastic vessels. Refers to vessels manufactured from a hard plastic that has the physical integrity to support its shape without the need for an external support, such as a tank or a tote. For example, PETG (polyethylene terephthalate glycol) bottles or PP (polypropylene) carboys.
- Flexible walled plastic vessels. Refers to vessels that are manufactured from a flexible polymer film, usually made up of multiple layers that is used to form 2 or 3 dimensional bags. 2D bags hang from a support stand while 3D bags require an external support tank or tote.

Comparison of Borosilicate Glass vs Single Use Plastic

Borosilicate Glass	Plastic
Reusable and sustainable	Reusable in very limited applications. Plastic is not long term sustainable as it is dependent on oil for raw material
Breakable, and requires care when handling but is robust when used correctly	Does not break easily under normal operating conditions but can become brittle over time. Can crack and splinter if dropped
Larger vessels are heavy and can be difficult to manipulate	Plastic is much lighter than glass. Rigid walled plastic vessels available up to 50L, flexible walled plastic vessels are available in a wide range of sizes and formats
Continually recyclable without experiencing downgrading or loss of quality. Approx 80% of glass is recycled vs <7% of plastics	Recycling plastic through use of reground materials can introduce defects into the structure of the product because the previous molding process, and the regrinding process itself may degrade the physical, chemical and flow properties of the resin.
Is considered older technology	Seen as new technology
Initial set up costs are higher than plastic equivalents	Direct plastic equivalent products are typically less expensive than their glass equivalents per run. However, the recurring consumable costs are higher over time as new products have to be used each time.
Needs to be cleaned between uses	Single use plastics are designed to be used once and is thrown away
Can be easily customized by master glass blowers	Are not easily customized. If a custom design is required, either existing tooling has to be adapted, or new molding tools have to be designed and built to manufacture the plastic parts. The cost of the design and the tools are usually the responsibility of the customer. For small numbers of products (<10,000) the cost of producing new tools is not usually financially attractive
Can be sterilized by autoclaving or dry heat	Only certain plastics can be sterilized by autoclaving, for others this is not an option. Very few polymers can withstand the temperatures required for effective dry heat sterilization
Can be depyrogenated by dry heat	Very few polymers can withstand the temperatures required for dry heat depyrogenation.
Can be flame sterilized	Cannot be flame sterilized
Borosilicate glass is stable to temperature down to -196°C	Most polymers are stable to temperatures down to -40°C. Some polymers are stable to -190°C.
Glass has an initial higher carbon footprint to produce than plastic	The production of polymers has an initially lower carbon footprint than glass. This is offset over time because plastics are by their nature single use while equivalent glass products can last decades
For critical applications needs to be cleaned and sterilized between use. Both processes must be validated and documented by the end user.	Single use plastic devices are typically supplied double bagged and sterilized by gamma irradiation. They do not require cleaning or sterilization. However, if the packaging is compromised, the

	product is not sterile, cannot be re-sterilized and must be thrown away.
Sterilization of larger vessels by autoclaving is limited by the availability of large autoclaves	For rigid walled plastic vessels autoclave size is also a limitation. Flexible walled plastic vessels are usually supplied presterilized, their materials of construction do not allow them to be sterilized by autoclaving.
Can be safety coated to improve handling, reduce leakage and eliminate glass shards in the environment	Flexible walled plastic vessels have an incorporated external layer in the film that is designed to reduce or limit the possibility of puncture damage. However, they are still prone to damage caused by mishandling, incorrect installation, contact with sharp objects, and abrasion
Is not dependent on fossil fuels for raw materials. Raw materials are locally sourced and processed.	All plastics have an extended raw material supply chain that is 100% dependent on secure oil supply and the fluctuating prices of crude oil
Stable supply chain – not dependent on the price of imported oil	Price changes based on supply and demand and can impact cost of goods at short notice. Price is 100% dependent on secure crude oil supply
Glass is unreactive to all common solutions, including most solvents, strong acids and bases	Plastics have limited chemical compatibility which varies depending on the type and grade of plastic material.
Can be easily and aggressively cleaned	Plastic systems are disposed of post use and are not usually cleaned.
Excellent chemical stability	Chemical stability is dependent on the type and grade of the plastic material.
Very low extractables and leachables profile	Each material in a single use assembly has to be tested to determine it's extractable and leachable profiles as well as long term stability to the product that is in contact
Clear glass does not fade over time – can see contents	Polymers can discolor over time making it hard to see the contents
Does not warp, melt or crack	Polymers can change over time depending on storage conditions
Does not age or become brittle on exposure to UV light	Polymers can age and become brittle on exposure to UV light
Glass systems can be sterilized by the user using wet heat, dry heat, or ethylene oxide. They can also be sterilized by gamma irradiation, X-rays, or E-beam.	Certain plastics cannot be sterilized by wet heat. Most cannot be sterilized by dry heat. Flexible walled based technologies have to be supplied presterilized as the films used are not stable to the temperatures required for wet or dry heat sterilization.
Does not discolor when gamma-irradiated	Many plastics undergo a color shift on exposure to gamma irradiation. Polycarbonate for example can go from clear to yellow on exposure to 25 – 40 kGy exposure. Color stabilizing compounds can be incorporated into the resin before molding to reduce the color shift, but it is not eliminated
Type 1, Class A borosilicate glass is approved for use with all biological compounds (USP<660>, revised 2023)	Each polymer has to undergo testing to ensure its suitability for use with the identified compound(s).

Single product contact surface	Many single use systems utilize multiple different plastics in their design. Each different material has to be tested for extractables, leachables and long-term stability to the products and drug substances
Over time glass is a much more cost-effective solution than single use plastic	Multiple independent studies show the long-term cost benefits of glass vs plastic laboratory components
Reduces plastic waste in the environment and lowers waste removal costs	Creates additional plastic waste which lead to higher waste removal costs
Glass vessels are self-supporting and do not require an external tank, vessel or tote to support them.	Rigid walled plastic vessels such as carboys can support themselves, however flexible walled plastic vessels require a support vessel to maintain their shape, prevent them collapsing in on themselves, and allow them to be used
Glass is not subject to potential pin holing because of vibrational frequency during transportation	Plastic flexible walled based systems can under specific conditions, be subject to vibration induced pin holing resulting in leaks.
Long term use of glass reduces carbon footprint and helps companies and institutions to achieve both climate and carbon neutrality goals	Plastic consumption does not reduce the carbon or climate footprint of a process

References.

1. Urbina, M. A., Watts, A. J. R., and Reardon, E. E. (2015). Labs should cut plastic waste too. *Nature* 528:479. doi: 10.1038/528479c
2. UNESCO Institute for Statistics. (2023). Bulk data download service. Available at: <https://uis.unesco.org/bdds>
3. OECD. (2022). Plastic pollution is growing relentlessly as waste management and recycling fall short, says OECD. Available at: <https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm>
4. Plastic waste worldwide – statistics & facts|Statista (2024). Available at: <https://www.statista.com/topics/5401/global-plastic-waste/#topicOverview>
5. 2050 long-term strategy - European Commission. (2020) Available at: https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en
6. Alves, J., Sargison, F. A., Stawarz, H., Fox, W. B., Huete, S. G., Hassan, A., et al. (2021). A case report: insights into reducing plastic waste in a microbiology laboratory. *Access Microbiol.* 3:173. doi: 10.1099/acmi.0.000173
7. Trusler EC, Davies M, Spurrier B and Gould SJ (2024) Reusable glassware for routine cell culture—a sterile, sustainable and affordable alternative to single-use plastics. *Front. Sustain.* 5:1447236. doi: 10.3389/frsus.2024.1447236

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