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Fundamental

ISPE Knowledge Brief

Environmental and Financial Benefits of Single-Use Technology

by Wayne Flaherty and Pietro Perrone, PE

Introduction

Have you considered single-use technology and wondered what to do with the products after use? This Knowledge Brief highlights the options available and what advantages can result. It also presents data and references that can help you understand and assess the benefits of single-use technology.

Implementation into Biopharmaceutical Processes

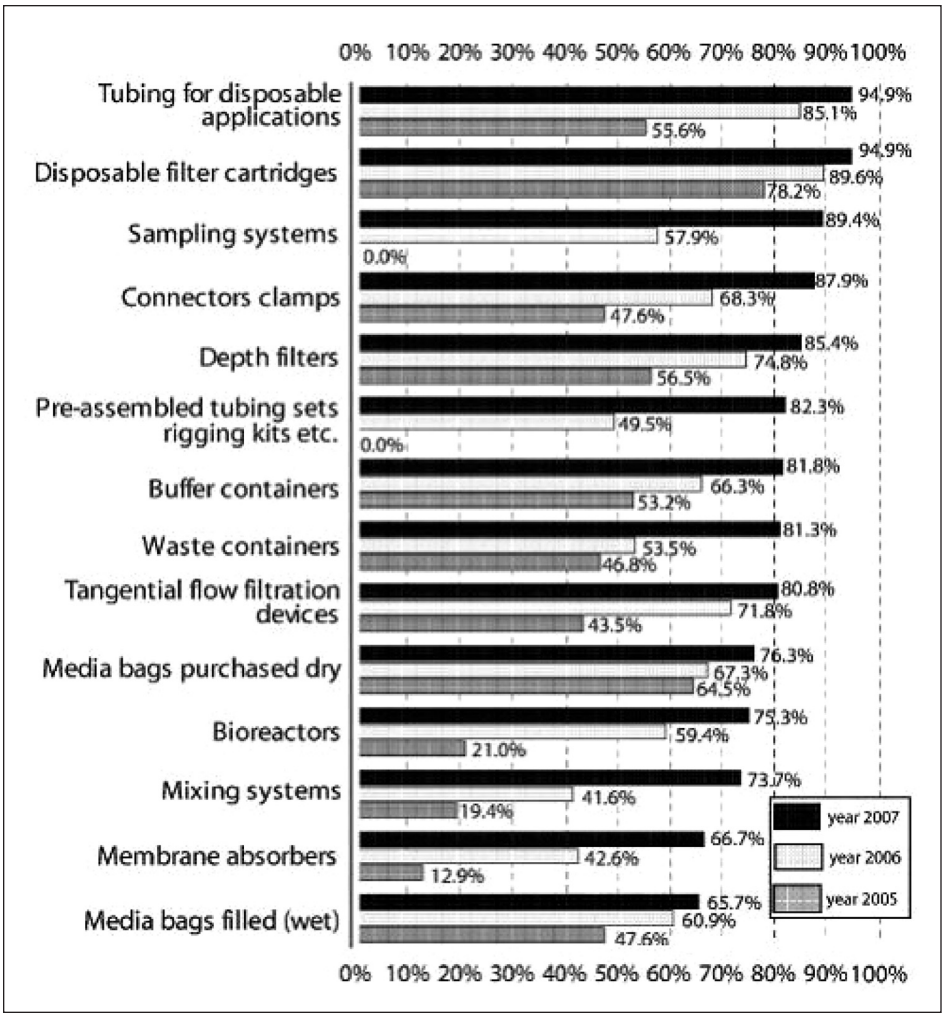
Single-use systems are used for a wide range of applications in biopharmaceutical manufacturing. The applications include the traditional filtration operations as well as other separation and purification steps. The manufacturers' need to minimize costs and maximize operational flexibility are important drivers for the rapid expansion of single-use technology into a number of applications that were traditionally the domain of stainless steel equipment. Primarily, these include bioreactors, buffer/media storage containers, mixers, bulk, and final filling equipment. This has resulted in significant growth for this new technology. The following chart shows that usage of single-use bioreactors and mixers have gone from ~20% to ~75% between 2005 and 2007.

The growth in single-use bioreactors is in part due to the effectiveness of the biopharmaceutical production processes. With higher titers, the need to have large (10,000 to 20,000 liters) bioreactors has diminished. The comparatively small size limitation (2,000 liter) for the single-use bioreactors is becoming more in line with production scale requirements.

While some process steps have been converted to single-use faster than others, virtually all process steps are now capable of being performed with single-use technology. At least one production facility employing 100% single-use components has been constructed and is in successful operation.[1]

The top three drivers in the decision to implement single-use technology include the following:[2]

1. eliminates cleanings
2. decreased risk of cross contamination
3. reduced startup and campaign turnaround time



For Users of Disposables: "Which types of single-use/disposable systems do you currently use in biopharmaceutical manufacturing?" *Source: BioPlan Associates Fifth Annual Report of Biopharmaceutical Manufacturing Capacity and Production, April 2008.*

Cost, Energy, and Resource Reduction Case Study

A case study at a biologicals manufacturing clinical plant (2x2000L fermentors) implemented single-use for sampling, buffer, and media prep indicates that implementation of single-use is good for the environment and the bottom line. The implementation generated the following benefits/savings:

- more than one million liters of WFI and purified water
- 28,812 kwh electrical power
- $250,000 in WFI generation costs (power and water)
- $60,000 in direct labor cost (set up and cleaning of stainless steel tanks)
- savings of >900 liters/yr of CIP100 and 450 liters/yr of CIP200 (~US$7,259)
- calculated carbon foot print reduction of > 20 metric tons of CO2 (per US EPA guidelines)

Note: carbon footprint reduction equates to 2,384 gallons of gas consumed or 59,600 miles driven by an average automobile.

While achieving the above benefits, single-use technology results in an increase of plastic waste. A recent report on the life cycle analysis of a single-use system states that the system's disposal accounts for 70% of the global warming potential incurred at the end phase of the single-use system's life cycle.[3]

Transportation contributes the other 30%. According to a model from the Dynamics of California's Biotechnology Industry,[4] the theoretical amount of plastic waste is estimated at about one ton per batch. If we consider that the typical plant processes 125 batches per year, the plant would produce 125 tons per year of plastic waste.

In 2002, there were 410 biotech manufacturing companies in California.[5] This grows to 850 companies today assuming a 10%/yr growth rate. If half of them were to produce one ton of plastic per batch, we would have 53,125 tons of plastic/year to handle from the biotech manufacturing production. What do we do with all that plastic?

Benefits from Implementing Single-Use Technology

There is beneficial synergy between minimizing the cost of operations and minimizing the impact on the environment. The effects are more evident at the beginning and the end of the operations where the components enter and leave the process. An evaluation of handling the operation at these two points provides insight on how your process can benefit.

Reduce

To minimize the amount of plastic in the single-use operation, one starts by minimizing the amount used in the process. Review with vendors existing designs for reduction opportunities and standardization, i.e., 10 different sample bag configurations may not be needed. Standardization will help reduce your warehousing space, QC workload, and purchasing complexity. These efficiency improvements will likely have a significant effect on reducing cost.

After minimizing the number of single-use components, there are three options for handling the products after use:

Re-Use

While this option should be considered, implementing it would be very difficult and it will increase contamination

risk, remove the ease-of-use benefits of applying single-use components, and may create impossible-to-handle regulatory issues.

Recycle

Single-use bags are multilayer films. The tubing assemblies and other auxiliary components in mixers and bioreactors are composed of different plastics. The need to separate plastics/film for the recycle route makes for a complex and expensive process. Repurposing the waste to other industries such as the concrete industry is an option that can be explored.

Reclaim

The main objective of this option is to recover what one can from the plastic by extracting the available energy inherent in the material. Plastic waste contains a large amount of stored energy, about 32.6 GJ/ton.[6] Using the production amount referenced earlier, the 53,125 tons of plastic waste could generate ~ 1.7 TJ or 460,000 kWh of power. *That's enough energy to power 50 homes for more than one year.* Reclamation through incineration has evolved to become the most practical and implementable solution.

Conclusion

The results presented here have been experienced through the technology's implementation into the traditional processes. Its continued successful acceptance will advance single-use technology into more applications and provide benefits to the users and the environment.

Manufacturers are making a concerted effort to:

- ✓ reduce costs
- ✓ reduce time to market
- ✓ reduce environmental impact of production

Single-use components help move in that direction.

- ✓ reduce water
- ✓ reduce energy use

Single-use technology has gone beyond a novelty to try on a limited basis. The full scale implementation has proven itself reliable and able to provide numerous financial and environmental benefits.

References

1. Single Use Technology: Approaches in Unique Facility Design, Successful Implementation and Exploring Future Growth Opportunities. ISPE Boston Chapter Program at Acceleron Pharma. May 2010.
2. BioPlan Associates Fifth Annual Report of Biopharmaceutical Manufacturing Capacity and Production, April 2008.
3. Life Cycle Assessment of a Millipore Mobius Buffer/Media Filtration System, Vikas Gupta, presented at the Biological Production Forum, Frankfurt, Germany, June 2010.
4. The Dynamics of California's Biotechnology Industry, Public Policy Institute of California, Junfu Zhang and Nikesh Patel, 2005.
5. The Dynamics of California's Biotechnology Industry, Public Policy Institute of California, Junfu Zhang and Nikesh Patel, 2005 and Ernst & Young, 2002.
6. Energy Savings By Wastes Recycling, Commissioned by European Economic Communities, Elsevier, London, 1985.
7. This Knowledge Brief is based on the technical presentation "Disposing of Disposables and Related Environmental Concerns" from the IBC program, June 14, 2010, presented by Wayne Flaherty of Compliance Concepts International. It is recommended that the reader also visit the ISPE Disposables Community of Practice (COP) for detailed communications among members of how single-use equipment is impacting their work.

For Further Information

For more detailed information, the following ISPE resources are available:

Pharmaceutical Engineering:

- "Biopharmaceutical Manufacturing in the Twenty-First Century – the Next Generation Manufacturing Facility" by Mark F. Witcher, PhD and Jeff Odum, CPIP, *Pharmaceutical Engineering,* March/April 2012, Volume 32, Number 2.
- "A Systematic and Scientific Approach for Implementation and Validation of Single Use Equipment" by Jean-Loup Descamps, Jean-Baptiste Milandri, and Peggy Sander, *Pharmaceutical Engineering,* May/June 2011, Volume 31, Number 3. http://pharmaceuticalengineering.org

Knowledge Briefs:

- "Method for Implementing Disposables into a Bioprocess Facility" by Adam Goldstein and Pietro Perrone. KB-0020-Mar10. http://www.ispe.org/publications/knowledge-briefs

Disposables Community of Practice:

- Visit the Disposables COP for the most current and up-to-the-minute discussions on the topics discussed in this Knowledge Brief and other related topics. http://www.ispe.org/disposablescop

About the Authors

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