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Application Note 01

# Economic evaluation of 3M™ Polisher ST replacing an AEX polishing column in a mAb manufacturing process

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## Introduction

With increasing molecule diversity, biologic drug manufacturers are looking for platformable manufacturing solutions. With a diversified portfolio still dominated by monoclonal antibody (mAb) therapeutic proteins, an important focus is placed on process intensification which helps in lower capital expenditure investment and overall manufacturing cost. The number of molecules in the development pipeline and time to market are key factors for success.

These trends have led to a surge in demand for single-use products and solutions. Single-use technologies (SUTs) offer reduced capital expenditure, allow faster turnaround between batches, can improve changeover time between campaigns and flexibility to deal with molecular diversity in the pipeline, and can benefit the speed to market. The ability to use reliable platform technologies across different processes and molecules further decreases the time required for process development and production of clinical material.

In the past decade, cell line development and optimized cell culture technologies have shifted the bottleneck from upstream processes (USP) towards the downstream process (DSP) operations. Titers at commercial scale have moved from less than 2 g/L and low cell density ($<10\times10^6$ cell/mL) processes to titers of over 7 g/L. Now the yield of the downstream operations has become the limiting factor for the output capacity of the manufacturing plant. In order to fully utilize the increased therapeutic protein mass produced, the number of downstream unit operations needs to be reduced, and the size of individual steps must be decreased to minimize product losses. New single-use technologies such as 3M™ Polisher ST provide manufacturers with opportunities to intensify manufacturing operations.

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## Single-use AEX Chromatography

**Figure 1:** *Traditional resin-based column (left) and holder with one BC16000 capsule of 3M™ Polisher ST (right).*

3M™ Polisher ST offers a single-use chromatography solution for the downstream manufacturing space, allowing replacement of multi-use chromatography columns as shown in Figure 1.

Single-use chromatography technology offers the flexibility a multiproduct manufacturing facility requires. Several studies have demonstrated that the capital investment required for a single-use facility is lower, and these facilities offer substantial time and labor savings by eliminating cleaning and cleaning validation procedures.[1,2]

In a multiproduct and multimodality facility, the downstream operations must keep pace with the product mass expressed by the upstream part of the process. When using existing technologies, the size of the downstream unit operations increases proportionately with the batch size and product titer.

Some of the recent technology innovations which have been tested and used in the industry include high-capacity chromatography resins with higher loadings and lower residence time. Adoption of single-use chromatographic membrane adsorbers in commercial scale downstream processes has lagged, primarily due to capacity limitations and concerns about cost effectiveness beyond lab and pilot scales. Sensitivity of the performance of AEX ligands to the process conditions, including pH, conductivity and buffer types, has hindered their application in the development of true platform processes.

To improve the overall process economics and to allow adoption of single-use equipment at any scale, disposable chromatography solutions need to show high throughput capacities and improve the product yield. In this application note, we discuss different strategies for the AEX flow-through polishing step. A comparison is made between a traditional reusable downstream polishing AEX column, a reusable AEX membrane adsorber and an advanced single-use AEX solution like 3M™ Polisher ST.

## 3M™ Polisher ST in the Biopharmaceutical Process

3M™ Polisher ST is a synthetic, hybrid polishing solution containing two complementary AEX-functional media: a quaternary ammonium (Q) functional nonwoven and a guanidinium-functional membrane (Figure 2).

The Q-functional nonwoven provides reduction of turbidity (when present), DNA, HCP, and endotoxin, and adds to the product's total charge capacity. Since 3M™ Polisher ST is capable of operating in turbid conditions, it can be placed directly after the low pH virus inactivation and neutralization step (VIN), without the need for any pre-filtration. Reusable columns and membrane adsorbers typically require to be protected by a depth filter and membrane to prevent fouling and pressure buildup after a certain number of cycles. 3M™ Polisher ST is designed for true single use, allowing non-reversible entrapment of particles, as a new capsule will be used for the next batch.

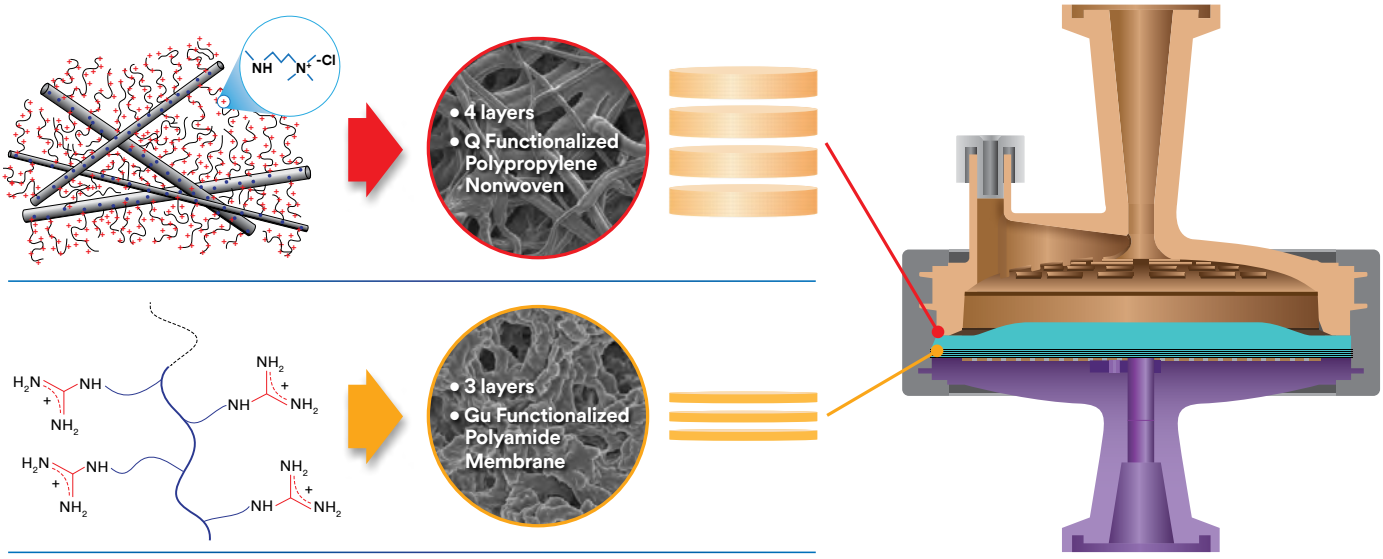


**Figure 2:** *Multi-layer capsule construction of 3M™ Polisher ST*

The novel guanidinium functional membrane reduces host cell protein impurities and provides robust viral clearance in a wide range of operating conditions, including high conductivity, low pH and polyvalent buffers. The expanded operating window of the guanidinium ligand allows more freedom in designing DSP polishing trains, offering potential for process simplification and facilitating the transition to true platform processes. The combination of the different functional layers results in a very high charge capacity, allowing typical mAb loadings of 10 kg/m$^2$ in a flowthrough mode. In this case, the m$^2$ refers to the frontal surface area of the system and is proportional to the bed volume of the chromatography media in the device. This enables deployment of 3M™ Polisher ST in the downstream process at all scales, including full commercial manufacturing.

## Modeling the Process

In this application note we explore the potential impact of replacement of an AEX flow-through column by a reusable membrane adsorber or the single use 3M™ Polisher ST on the cost of monoclonal antibody therapeutic manufacturing. This work describes hypothetical scenarios. Depending on product and process conditions, the effects covered in this application note may not be realized or may not be realized to the degree shown in the scenarios.

We modeled a typical single-use large scale manufacturing facility using the commercial Biosolve Process™ software package (version 8.3) from Biopharm Services Limited. The facility and process have the following attributes:

- Reactor setup: 6 single-use bioreactors with 2000 L working volume
- mAb titer = 5 g/L
- 1 reactor is harvested and purified at a time.
- Facility output of 100 batches per year
- Downstream operations utilize single-use systems as much as possible

Table 1 lists the process parameters used for the three technologies that are being compared, a traditional column, a membrane adsorber that can be cycled 100 times and a single use AEX capsule. The column and membrane adsorber are protected by a depth filter and membrane to prevent fouling, while 3M™ Polisher ST is applied immediately after VIN.

This investigation covers the key potential advantages of deploying 3M™ Polisher ST in the biopharmaceutical manufacturing process. A commercial manufacturing sized 3M™ Polisher ST BC16000 capsule was used as the standard consumable format for the models. For the membrane adsorber, a capsule with 2.5 L bed volume was used for modelling.

The theoretical recovery of 3M™ Polisher ST is around 99%, even if up to 50% of the membrane's protein binding capacity is used for unwanted binding of the target mAb. Experimental data has shown recoveries of at least 95% for the entire intended operating range and has confirmed values around 99% to be realistic under optimized conditions. The same recovery of 99% is assumed for the reusable membrane adsorber.

Biosolve Process is an expansive model utilizing an enormous dataset from the industry in terms of operational strategy and cost. Cost databases from the software were maximally utilized. It is not possible to account for every scenario and detail. To investigate how certain parameters affect the results, and which inputs are most critical, a sensitivity analysis was performed.

| Parameters | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| **AEX step** | AEX column | Membrane adsorber (MA) | 3M™ Polisher ST |
| **Post VIN DF recovery** | 95% | 95% | NA |
| **Post VIN membr. rec.** | 98% | 98% | NA |
| **Step recovery** | 95% | 99% | 99% |
| **Hardware** | column | none | EZA holder |
| **Consumable cost** | 2,380 $/L | 30,000 $/capsule | 5,500 $/caspsule |
| **Loading** | 200 g/L | 3 kg/L | 10 kg/m$^2$ |
| **Target cycles / batch** | 1 cycle | 1 cycle | 1 cycle |
| **Max # cycles** | 150 cycles | 100 cycles | 1 cycle |

**Table 1:** *Main parameters and assumptions used for the different flow-through AEX solutions.*

## Scenario 1: Typical mAb process with reusable AEX column

***Total DSP yield: 58 %***


| Parameter | DF 1 | DF 2 | Membrane | Capture | VIN | DF | Membrane | AEX column | CEX column | Virus filter | UF/DF | Membrane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Size** | 14 pc | 7 pc | 30" | 62 L | NA | 1 pc | 10" | 62 L | 78 L | 2 pc | 6,8 m² | 10" |
| **Batch load** | 100 L/m² | 200 L/m² | 1000 L/m² | 35 g/L (4 cycles) | NA | 400 L/m² | 1000 L/m² | 200 g/L (1 cycle) | 60 g/L (2 cycles) | 5000 g/m² | NA | 250 L/m² |
| **Yield %** | 90 | 95 | 98 | 90 | 98 | 95 | 98 | 95 | 95 | 98 | 98 | 98 |

**Figure 3:** *Base process with traditional resin-based AEX column.*

| Overall Yield | PMI | COGS $/g |
|---|---|---|
| **58%** | **4,842** | **63.66** |

**Table 2:** *Yield, PMI and COGS for scenario 1.*

The base scenario consists of a typical mAb process with a two-stage depth filter clarification, a protein A capture step, VIN, protective filtration steps and two polishing chromatography column steps. Figure 3 shows the overall process model and the main parameters for each process step. The AEX column has a packed resin volume of 62 L. The batch is processed in a single cycle with a load of 200 g/L. The resin is reused for 150 cycles.

More detailed information on the process sequence and cost breakdown are included in the Appendix.

The DSP yield of the scenario 1 process is 58%. The summary table 2 includes the overall yield, Cost of Goods Sold (COGS) in US dollars per gram of mAb and the process mass intensity (PMI) index. This last key performance indicator is the total mass of materials, including buffers and water, used in the process, divided by the mass output of the product of interest.[3,4] The PMI is seen as an indicator for the environmental impact of the process. Lower PMI values are associated with a lower environmental footprint, less waste and generally also lower costs.

## Scenario 2: mAb process with reusable AEX membrane adsorber

***Total DSP yield: 61 %***


| Parameter | DF 1 | DF 2 | Membrane | Capture | VIN | DF | Membrane | Membrane adsorber | CEX column | Virus filter | UF/DF | Membrane |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Size** | 14 pc | 7 pc | 30" | 62 L | NA | 1 pc | 10" | **2.5 L** | 78 L | 2 pc | 6,8 m² | 10" |
| **Batch load** | 100 L/m² | 200 L/m² | 1000 L/m² | 35 g/L (4 cycles) | NA | 400 L/m² | 1000 L/m² | **3 kg/L** | 60 g/L (2 cycles) | 5000 g/m² | NA | 250 L/m² |
| **Yield %** | 90 | 90 | 98 | 90 | 98 | 95 | 98 | **99** | 95 | 98 | 98 | 98 |

**Figure 4:** *mAb process with reusable AEX membrane adsorber*

| Overall Yield | PMI | COGS $/g |
|---|---|---|
| **61%** | **4,383** | **60.36** |
| (+3% compared to scenario 1) | (-9% compared to scenario 1) | (-5% compared to scenario 1) |

**Table 3:** *Yield, PMI and COGS for scenario 2.*

In scenario 2, the traditional AEX column is replaced by a membrane adsorber capsule. The batch is processed with a single 2.5 L capsule. The assumption is that the membrane can be regenerated and reused for 100 batches. To prevent fouling and pressure increases, the adsorber is positioned after the VIN depth filter and membrane, as shown in Figure 4.

Table 3 summarizes the results. Due to the smaller size of the membrane and its convective flow path, the recovery of the AEX step is increased from 95% to 99%. With that, the overall DSP recovery increases from 58% to 61%.

## Scenario 3: mAb process with single use 3M™ Polisher ST step

***Total DSP yield: 65 %***


| Parameter | DF 1 | DF 2 | Membrane | Capture | VIN | 3M™ Polisher ST | CEX column | Virus filter | UF/DF | Membrane |
|---|---|---|---|---|---|---|---|---|---|---|
| **Size** | 14 pc | 7 pc | 30" | 62 L | NA | **1 x BC16000** | 78 L | 2 pc | 6,8 $m^2$ | 10" |
| **Batch load** | 100 L/$m^2$ | 200 L/$m^2$ | 1000 L/$m^2$ | 35 g/L (4 cycles) | NA | **10 kg/$m^2$** | 60 g/L (2 cycles) | 5000 g/$m^2$ | NA | 250 L/$m^2$ |
| **Yield %** | 90 | 90 | 98 | 90 | 98 | **99%** | 95 | 98 | 98 | 98 |

**Figure 5:** *Model process with traditional depth filters and single-use AEX step.*

| Overall Yield | PMI | COGS $/g |
|---|---|---|
| **65%** | **4,070** | **55.37** |
| (+7% compared to scenario 1) | (-16% compared to scenario 1) | (-13% compared to scenario 1) |

**Table 4:** *Yield, PMI and COGS for process with single use AEX.*

3M™ Polisher ST is an advanced single-use solution containing two complementary AEX-functional media: A Q-functional nonwoven and a guanidinium-functional membrane. Due to its high capacity and unique guanidinium functionality, the 3M™ Polisher ST offers higher mAb loading than a traditional flow-through Q resin. The high capacity and convective flow of the membrane enables downsizing of the AEX polishing unit operation, while achieving an equivalent effluent quality in terms of turbidity, DNA and HCP levels.

Scenario 3 shows the effect of deploying 3M™ Polisher ST in the process. The batch is still processed in one cycle and the capsules are not reused. Due to its ability to operate in moderate levels of turbidity, the depth and membrane filtration steps after virus inactivation and neutralization (VIN) can be eliminated. The process is simplified from 12 recovery and downstream unit operations to 10.

Due to the elimination of the protective filtration steps, the overall DSP yield further increases to 65%. The cost of manufacturing is decreased by 13% compared to scenario 1 and by 8% compared to scenario 2.

## Cost breakdown

The AEX polishing chromatography step is not a main cost driver of the process. In scenario 1, the most cost intensive process steps are the production bioreactor (29% of total batch cost) and the protein A capture step (16%). The AEX polishing column is responsible for 7% of the total batch cost, while 3M™ Polisher ST accounts for 5% in the third scenario.

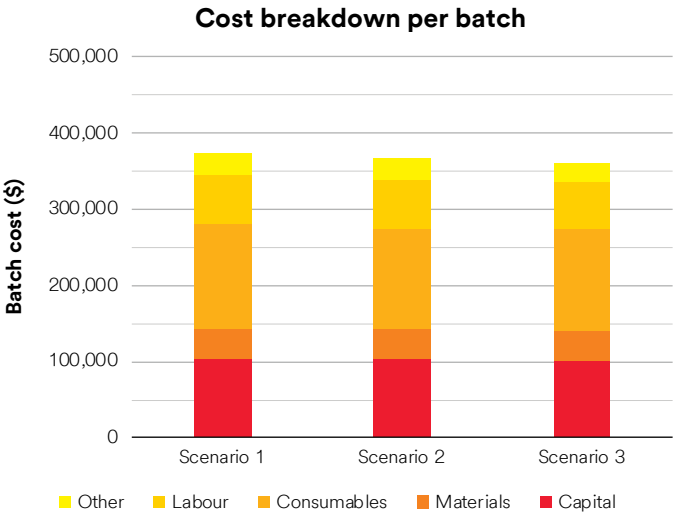


**Figure 6:** *Total cost per batch for different scenarios*

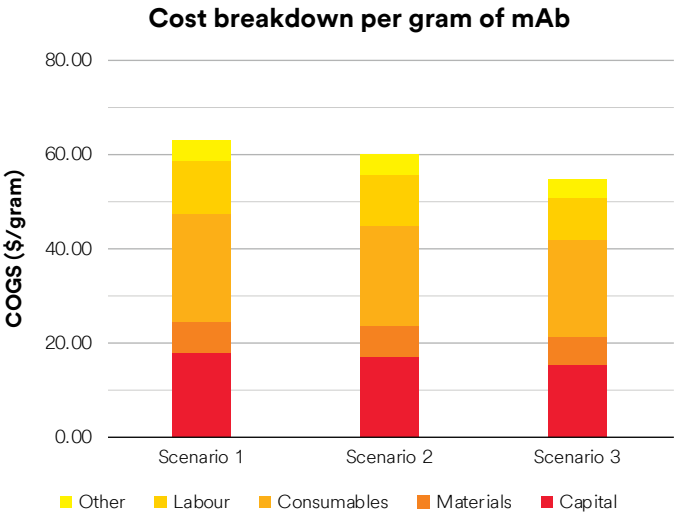


**Figure 7:** *Cost breakdown for different scenarios on per gram basis*

Implementation of advanced single use technology and driving intensification reduces the cost of the model processes. Figures 6 and 7 show a cost breakdown to explain the main drivers of those changes. These graphs show the total production cost of the entire process, not just the process steps that are being investigated. The production cost per batch is relative stable across the scenarios and decreases by only 3% for scenario 3 compared to scenario 1. However, the cost per gram of mAb produced is reduced by 13%. This difference is explained by an increased recovery in the single use scenario, resulting in a higher overall mAb output per batch. This yield effect is the strongest contributing factor to the cost savings.

Implementing single-use devices with a small footprint and eliminating steps strongly contributes to higher overall process yield. Figure 8 shows how the improved DSP recovery for scenario 3 directly translates into a 12% increase in the annual plant capacity and number of doses available for sale. This is the primary reason why process simplification and intensification are crucial for biopharmaceutical manufacturers and their patients.

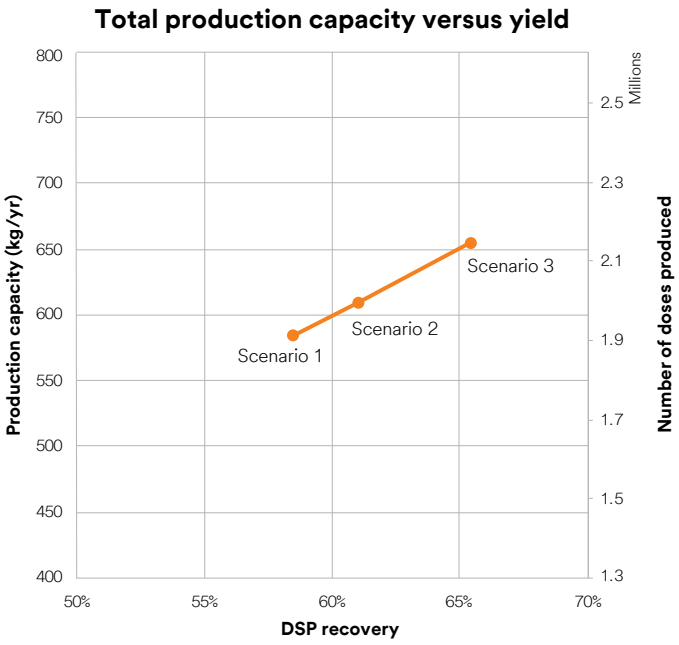


**Figure 8:** *Process intensification results in higher yearly plant output*

## Sensitivity analysis of process parameters

Selected input parameters were varied to study their effect on the total COGS. The load of the AEX step proved to have limited impact on the total process cost. Figure 9 shows a broad range of loadings between 50-400 g/L for the resin based AEX column and 2.5-20 kg/m² for 3M™ Polisher ST. For different loading levels, the required number of production capsules (pieces, pc) or resin volume after packing is shown. A single production capsule of 3M™ Polisher ST can process the batch from a 2000 L bioreactor for loadings between 5-20 kg/m². At 2.5 kg/m² loading (1/4 of the typical target loading), two capsules are needed, but this increases the total cost by only 2%.

At high impurity loads, it is more economical to use two capsules of 3M™ Polisher ST (COGS: 56.3 $/g) than it is to combine a depth filter and 3M™ Polisher ST at the normal loading (COGS: 58.7 $/g). At loads of 20 kg/m² or more, it becomes more economical to switch to the smaller BC2300 capsules of 3M™ Polisher ST.

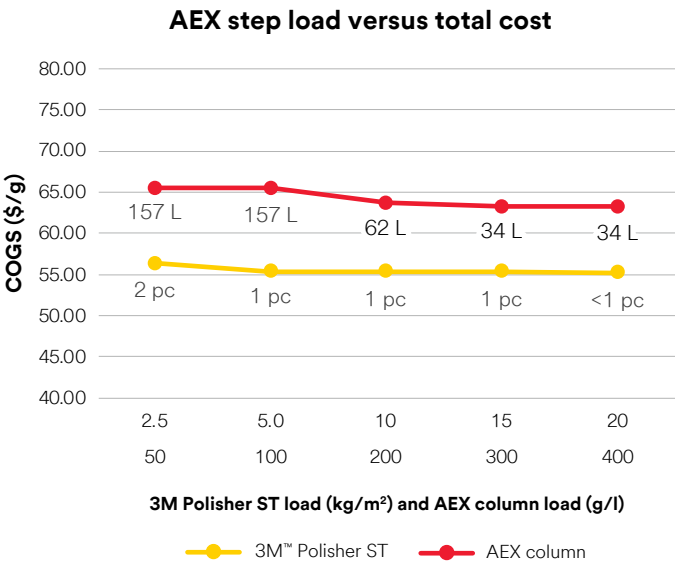


**Figure 9:** *Effect of AEX step load on total cost of goods*

In scenario 1, the lifetime of the AEX resin was set to 150 cycles. When this number was varied between 50 and 300, this resulted in less than 1% change in the total cost, as shown in Figure 10. If the AEX resin is used for less than 10 cycles, the cost increases strongly. The COGS for scenario 2, using the membrane adsorber, varied between 60.36 $/g when used for 100 cycles to 65.24 $/g when used only once. As expected, the membrane adsorber offers the largest benefits over the column when a low number of cycles is applied.

The manufacturing cost when using 3M™ Polisher ST once is 55.37 $/g, which is more economical than using the other membrane adsorber for 100 cycles. Hypothetical reuse of 3M™ Polisher ST for 10 or 100 cycles would result in a less than 1% change in the total cost. Small consumable savings would be offset by increases in buffer and labor cost, which would drive the cost slightly up, rather than down. Even if elution and regeneration of 3M™ Polisher ST were possible, it would not make sense economically.

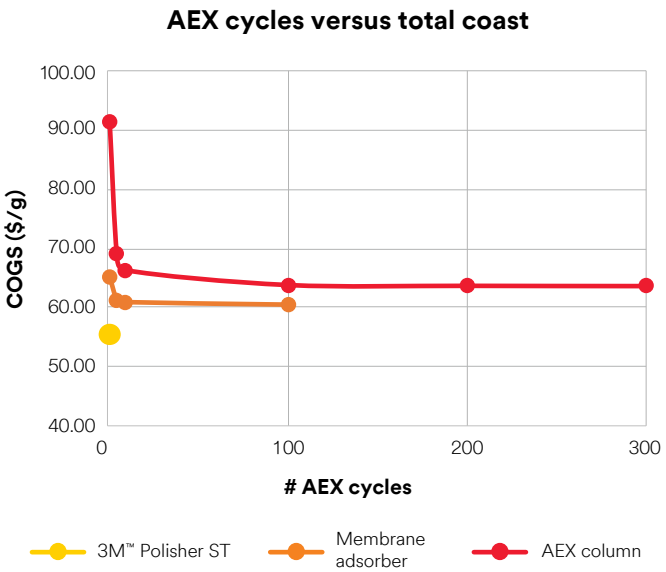


**Figure 10:** *Effect of number of AEX cycles*

As mentioned in the previous section, the total DSP recovery has the largest impact on the process economics. In Figure 11, a representative range of unit recovery of the AEX step is shown for the different technologies. Due to their smaller size, functionalized membrane capsules generally result in a higher product recovery than columns. Even at worst case conditions of 95% yield, 3M™ Polisher ST results in significant cost savings compared to the first scenario (9% savings instead of 13% at 99% recovery). With depth filters generally being required to protect the AEX column, the recovery across the filter will also impact the overall yield and cost. In Figure 11, this effect is shown for a depth filter recovery of 90% versus 95%.

## Sensitivity analysis of process parameters *(continued)*

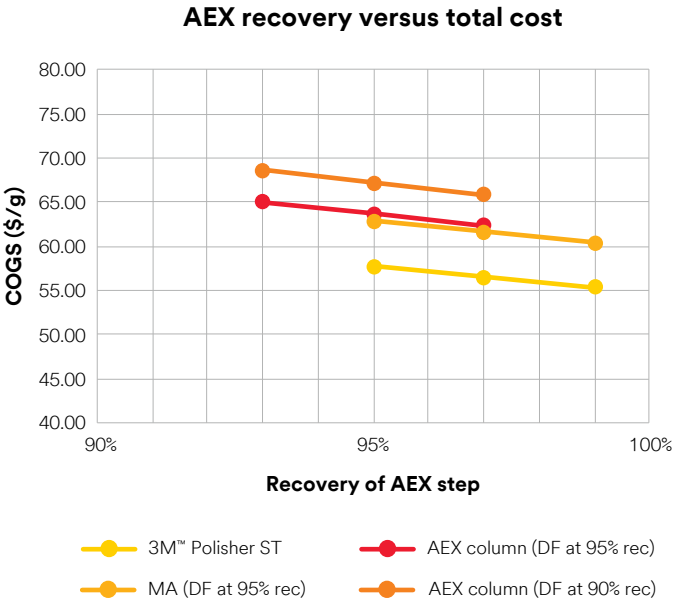


**Figure 11:** *AEX recovery is directly correlated to cost of goods*

The post VIN filtration steps are not expensive and account for only 2% of the batch cost in scenario 1, but these additional steps inevitably result in some product loss. Figure 12 shows the cost each of the technologies would have with and without protective filtration steps in front of them. Resin-based columns and membrane adsorbers typically need those filtration steps to prevent fouling and plugging, while 3M™ Polisher ST can operate in turbid, non-prefiltered conditions.

In case the AEX column is replaced by 3M™ Polisher ST without elimination of the depth filter and the membrane, the cost is reduced by 8%. When the filtration steps are removed, the cost is reduced by 13%. This means that most of the cost savings are due to the transition of the AEX step to a SUT but eliminating filtration steps further reduces the cost significantly.

The cost of the reusable membrane adsorber is shown for one cycle (single use) and 100 cycles. It is equally cost effective to use the membrane adsorber just once without pre-filtration than it is to include protective filters that enable reusing the adsorber 100 times.

3M™ Polisher ST, which is designed to be used without pre-filters, has the lowest cost of the three options. This data confirms that it is more cost effective to apply a true single use solution that can operate in the presence of turbidity than it is to have a membrane or column that can be reused.

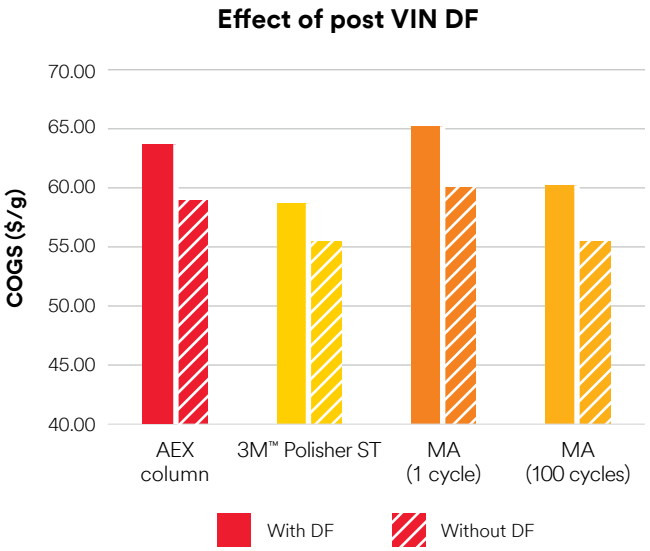


**Figure 12:** *Effect of elimination of filtration steps*

## Conclusion

3M™ Polisher ST can replace a multi-use AEX chromatography column or reusable membrane adsorber in large scale processes due to its high capacity and high recommended loading of 10 kg/m$^2$ of mAb. It is an economically viable alternative to reusable AEX products and can even reduce the cost of goods. 3M™ Polisher ST performance in AEX polishing unit operations can provide process simplifications that decrease the size and number of process steps and, thus, improve the productivity of the process.

If only the AEX column is replaced by 3M™ Polisher ST, the cost for the presented models is reduced by 8%. When the number of process steps is reduced by eliminating a protective depth filter and membrane, the cost savings increase to 13%. Compared to a reusable membrane adsorber, 3M™ Polisher ST offers an 8% decrease in cost.

The post VIN filtration steps have a negligible consumable cost but can result in a significant loss of the precious mAb product. These filtration steps are critical to prevent fouling and pressure increases on reusable chromatography products. With 3M™ Polisher ST being designed for single use and operation in turbid conditions, those protective filtration steps are no longer required. Our models show that it is more cost effective to have a true single use capsule than it is to regenerate and reuse.

Product recovery is one of the most important parameters for improving the cost of goods. Due to its small size and the reduction of process steps, 3M™ Polisher ST increases the total DSP recovery. Lower product losses directly result in a higher annual plant capacity and more doses being produced.

| Model | Overall Yield | Annual capacity | Doses produced | PMI | COGS |
|---|---|---|---|---|---|
| **Scenario 1 (column)** | **58 %** | **584.4 kg** | **1.9 million** | **4,842** | **63.66 $/g** |
| **Scenario 2 (membrane)** | **61 %** | **609.0 kg** | **2.0 million** | **4,383** | **60.36 $/g** |
| **Scenario 3 (3M™ Polisher ST)** | **65 %** | **654.2 kg** | **2.2 million** | **4,070** | **55.37 $/g** |
| Scenario 3 benefits over scenario 1 | +7 % | +12 % | +12 % | -16% | -13% |
| Scenario 3 benefits over scenario 2 | +4 % | +7% | +7% | -7% | -8% |

**Table 5:** *Summary results of comparison between AEX column, membrane adsorber and 3M™ Polisher ST*

## References


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# Appendix

## A. Scenario 1 process

### Table 6: *Scenario 1 - process sequence*

| No | Process Stage | Unit Op Name | Conc (g/L) | Yield (%) | Duration (hr) | Adjusted Duration (hr) | Mass In (g) | Mass Out (g) | Vol In (L) | Vol Out (L) | Target Out | Capacity Out (kg/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Feed | 0.0 | | | | | | | 16.0 | | |
| 1 | Upstream | N-2 Seed | 0.0 | 0% | 184.5 | 61.5 | 0.0 | 0.0 | 16.0 | 80.0 | 0.0 | 0.0 |
| 2 | Upstream | N-1 Seed | 0.0 | 0% | 184.5 | 61.5 | 0.0 | 0.0 | 80.0 | 400.0 | 0.0 | 0.0 |
| 3 | Upstream | Production | 5.0 | 100% | 390.5 | 65.1 | 0.0 | 10,000.0 | 400.0 | 2,000.0 | 10.0 | 1,000.0 |
| 4 | Recovery | Primary depth filter | 4.3 | 90% | 2.0 | 2.0 | 10,000.0 | 9,000.0 | 2,000.0 | 2,112.0 | 9.0 | 900.0 |
| 5 | Recovery | Secondary depth filter | 3.9 | 95% | 1.7 | 1.7 | 9,000.0 | 8,550.0 | 2,112.0 | 2,168.0 | 8.6 | 855.0 |
| 6 | Purification | Filtration (0.2um) | 3.8 | 98% | 2.1 | 2.1 | 8,550.0 | 8,379.0 | 2,168.0 | 2,179.8 | 8.4 | 837.9 |
| 7 | Purification | Protein A | 15.1 | 90% | 11.6 | 27.6 | 8,379.0 | 7,541.1 | 2,179.8 | 498.8 | 7.5 | 754.1 |
| 8 | Purification | Virus Inactivation | 14.5 | 98% | 4.5 | 4.5 | 7,541.1 | 7,390.3 | 498.8 | 508.8 | 7.4 | 739.0 |
| 9 | Recovery | Depth filtration | 13.6 | 95% | 2.0 | 2.0 | 7,390.3 | 7,020.8 | 508.8 | 516.8 | 7.0 | 702.1 |
| 10 | Purification | Filtration (0.2um) | 13.2 | 98% | 1.9 | 1.9 | 7,020.8 | 6,880.3 | 516.8 | 520.7 | 6.9 | 688.0 |
| 11 | Purification | AIEX Flow Through | 12.6 | 95% | 4.6 | 4.6 | 6,880.3 | 6,536.3 | 520.7 | 520.7 | 6.5 | 653.6 |
| 12 | Purification | IEX Bind & Elute | 13.3 | 95% | 8.7 | 8.7 | 6,536.3 | 6,209.5 | 520.7 | 467.6 | 6.2 | 621.0 |
| 13 | Purification | Viral Filtration | 12.7 | 98% | 3.0 | 3.0 | 6,209.5 | 6,085.3 | 467.6 | 477.6 | 6.1 | 608.5 |
| 14 | Purification | UF/DF | 50.0 | 98% | 8.1 | 8.1 | 6,085.3 | 5,963.6 | 477.6 | 119.3 | 6.0 | 596.4 |
| 15 | Purification | Filtration (0.2um) | 47.4 | 98% | 1.0 | 1.0 | 5,963.6 | 5,844.3 | 119.3 | 123.2 | 5.8 | 584.4 |

### Table 7: *Scenario 1 process - cost of goods breakdown (USD per batch)*

| | N-2 Seed | N-1 Seed | Production | Primary depth filter | Secondary depth filter | Filtration (0.2um) | Protein A | Virus Inactivation | Depth Filtration | Filtration (0.2um) | AIEX Flow Through | IEX Bind & Elute | Viral Filtration | UF/DF | Filtration (0.2um) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Equipment (Total)** | 724,994 | 1,136,934 | 5,289,622 | 121,375 | 60,688 | 113,943 | 1,154,310 | 170,725 | 23,071 | 101,684 | 967,800 | 1,106,682 | 90,593 | 535,809 | 75,132 |
| **Capital** | 6,518 | 10,222 | 47,558 | 1,091 | 546 | 1,024 | 10,378 | 1,535 | 207 | 914 | 8,701 | 9,950 | 815 | 4,817 | 676 |
| **Materials** | 1,735 | 4,016 | 14,725 | 1,194 | 1,179 | 1,452 | 5,118 | 1,165 | 1,166 | 1,165 | 1,588 | 1,690 | 1,167 | 1,322 | 1,165 |
| **Consumables** | 4,412 | 5,306 | 16,664 | 17,898 | 7,917 | 1,169 | 32,377 | 2,963 | 1,131 | 464 | 9,037 | 8,602 | 21,960 | 3,658 | 1,464 |
| **Labour** | 2,869 | 3,211 | 18,283 | 1,088 | 864 | 3,334 | 9,673 | 2,764 | 877 | 839 | 5,555 | 9,332 | 1,304 | 4,534 | 418 |
| **Other** | 1,628 | 2,565 | 11,939 | 373 | 186 | 516 | 2,893 | 385 | 59 | 229 | 2,240 | 2,630 | 206 | 1,241 | 170 |
| | **5%** | **7%** | **29%** | **6%** | **3%** | **2%** | **16%** | **2%** | **1%** | **1%** | **7%** | **9%** | **7%** | **4%** | **1%** |
| **Perfusion Factor** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Capital Charge** | 6,518 | 10,222 | 47,558 | 1,091 | 546 | 1,024 | 10,378 | 1,535 | 207 | 914 | 8,701 | 9,950 | 815 | 4,817 | 676 |
| **Materials** | 1,735 | 4,016 | 14,725 | 1,194 | 1,179 | 1,452 | 5,118 | 1,165 | 1,166 | 1,165 | 1,588 | 1,690 | 1,167 | 1,322 | 1,165 |
| **Media** | 570 | 2,852 | 13,560 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Buffer** | 0 | 0 | 0 | 30 | 15 | 3 | 3,954 | 1 | 2 | 1 | 424 | 525 | 3 | 158 | 1 |
| **Direct RM** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Bought WFI & PW** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **CIP** | 0 | 0 | 0 | 0 | 0 | 285 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **QC tests** | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 |
| **Consumables** | 4,412 | 5,306 | 16,664 | 17,898 | 7,917 | 1,169 | 32,377 | 2,963 | 1,131 | 464 | 9,037 | 8,602 | 21,960 | 3,658 | 1,464 |
| **Resins/MA** | 0 | 0 | 0 | 0 | 0 | 0 | 26,959 | 0 | 0 | 0 | 1,088 | 3,006 | 0 | 0 | 0 |
| **Bags** | 4,412 | 5,306 | 16,664 | 2,064 | 0 | 0 | 4,477 | 2,963 | 0 | 0 | 7,949 | 5,596 | 1,160 | 1,000 | 1,000 |
| **Filters** | 0 | 0 | 0 | 15,834 | 7,917 | 1,169 | 941 | 0 | 1,131 | 464 | 0 | 0 | 20,800 | 2,658 | 464 |
| **Packages** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Other** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Labour** | 2,869 | 3,211 | 18,283 | 1,088 | 864 | 3,334 | 9,673 | 2,764 | 877 | 839 | 5,555 | 9,332 | 1,304 | 4,534 | 418 |
| **Process** | 1,205 | 1,349 | 7,680 | 457 | 363 | 1,401 | 4,064 | 1,161 | 368 | 353 | 2,334 | 3,920 | 548 | 1,905 | 176 |
| **Quality** | 1,206 | 1,350 | 7,684 | 457 | 363 | 1,401 | 4,066 | 1,162 | 369 | 353 | 2,335 | 3,922 | 548 | 1,906 | 176 |
| **Indirect** | 458 | 513 | 2,919 | 174 | 138 | 532 | 1,544 | 441 | 140 | 134 | 887 | 1,490 | 208 | 724 | 67 |
| **Other** | 1,628 | 2,565 | 11,939 | 373 | 186 | 516 | 2,893 | 385 | 59 | 229 | 2,240 | 2,630 | 206 | 1,241 | 170 |
| **Insurance/other** | 338 | 530 | 2,467 | 57 | 28 | 53 | 538 | 80 | 11 | 47 | 451 | 516 | 42 | 250 | 35 |
| **Waste mgmt** | 0.99 | 1.53 | 5.53 | 32.71 | 15.33 | 1.78 | 5.82 | 2.19 | 2.19 | 0.29 | 7.23 | 5.12 | 1.98 | 0.87 | 0.71 |
| **Maintenance** | 306 | 481 | 2,236 | 51 | 26 | 48 | 488 | 72 | 10 | 43 | 409 | 468 | 38 | 226 | 32 |
| **Utilities** | 983 | 1,553 | 7,230 | 233 | 116 | 413 | 1,861 | 231 | 36 | 139 | 1,372 | 1,641 | 124 | 764 | 103 |
| **TOTAL (USD)** | **17,162** | **25,321** | **109,169** | **21,645** | **10,691** | **7,496** | **60,440** | **8,812** | **3,440** | **3,612** | **27,122** | **32,204** | **25,452** | **15,573** | **3,893** |
| **Total (USD/Gram normalized for the output)** | **2.9** | **4.3** | **18.7** | **3.7** | **1.8** | **1.3** | **10.3** | **1.5** | **0.6** | **0.6** | **4.6** | **5.5** | **4.4** | **2.7** | **0.7** |

# Appendix *(continued)*

## *B. Scenario 2 process*

### Table 8: *Scenario 2 - process sequence*

| No | Process Stage | Unit Op Name | Conc (g/L) | Yield (%) | Duration (hr) | Adjusted Duration (hr) | Mass In (g) | Mass Out (g) | Vol In (L) | Vol Out (L) | Target Out | Capacity Out (kg/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Feed | 0.0 | | | | | | | 16.0 | | |
| 1 | Upstream | N-2 Seed | 0.0 | 0% | 184.5 | 61.5 | 0.0 | 0.0 | 16.0 | 80.0 | 0.0 | 0.0 |
| 2 | Upstream | N-1 Seed | 0.0 | 0% | 184.5 | 61.5 | 0.0 | 0.0 | 80.0 | 400.0 | 0.0 | 0.0 |
| 3 | Upstream | Production | 5.0 | 100% | 390.5 | 65.1 | 0.0 | 10,000.0 | 400.0 | 2,000.0 | 10.0 | 1,000.0 |
| 4 | Recovery | Primary depth filter | 4.3 | 90% | 2.0 | 2.0 | 10,000.0 | 9,000.0 | 2,000.0 | 2,112.0 | 9.0 | 900.0 |
| 5 | Recovery | Secondary depth filter | 3.9 | 95% | 1.7 | 1.7 | 9,000.0 | 8,550.0 | 2,112.0 | 2,168.0 | 8.6 | 855.0 |
| 6 | Recovery | Filtration (0.2um) | 3.8 | 98% | 2.1 | 2.1 | 8,550.0 | 8,379.0 | 2,168.0 | 2,179.8 | 8.4 | 837.9 |
| 7 | Purification | Protein A | 15.1 | 90% | 11.6 | 27.6 | 8,379.0 | 7,541.1 | 2,179.8 | 498.8 | 7.5 | 754.1 |
| 8 | Purification | Virus Inactivation | 14.5 | 98% | 4.5 | 4.5 | 7,541.1 | 7,390.3 | 498.8 | 508.8 | 7.4 | 739.0 |
| 9 | Purification | Depth filtration | 13.6 | 95% | 2.0 | 2.0 | 7,390.3 | 7,020.8 | 508.8 | 516.8 | 7.0 | 702.1 |
| 10 | Purification | Filtration (0.2um) | 13.2 | 98% | 2.2 | 2.2 | 7,020.8 | 6,880.3 | 516.8 | 520.7 | 6.9 | 688.0 |
| 11 | Purification | Membrane adsorber | 12.5 | 99% | 0.8 | 0.8 | 6,880.3 | 6,811.5 | 520.7 | 545.7 | 6.8 | 681.2 |
| 12 | Purification | IEX Bind & Elute | 13.8 | 95% | 8.8 | 8.8 | 6,811.5 | 6,471.0 | 545.7 | 467.6 | 6.5 | 647.1 |
| 13 | Purification | Viral Filtration | 13.3 | 98% | 3.0 | 3.0 | 6,471.0 | 6,341.5 | 467.6 | 477.6 | 6.3 | 634.2 |
| 14 | Purification | UF/DF | 50.0 | 98% | 8.2 | 8.2 | 6,341.5 | 6,214.7 | 477.6 | 124.3 | 6.2 | 621.5 |
| 15 | Purification | Filtration (0.2um) | 47.5 | 98% | 1.0 | 1.0 | 6,214.7 | 6,090.4 | 124.3 | 128.2 | 6.1 | 609.0 |

### Table 9: *Scenario 2 process - cost of goods breakdown (USD per batch)*

| | N-2 Seed | N-1 Seed | Production | Primary depth filter | Secondary depth filter | Filtration (0.2um) | Protein A | Virus Inactivation | Depth Filtration | Filtration (0.2um) | Membrane adsorber | IEX Bind & Elute | Viral Filtration | UF/DF | Filtration (0.2um) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Equipment (Total)** | 728,849 | 1,142,980 | 5,317,751 | 124,079 | 62,039 | 114,765 | 1,177,440 | 175,566 | 23,340 | 102,296 | 696,851 | 1,166,491 | 91,259 | 551,873 | 75,603 |
| **Capital** | 6,562 | 10,291 | 47,878 | 1,117 | 559 | 1,033 | 10,601 | 1,581 | 210 | 921 | 6,274 | 10,502 | 822 | 4,969 | 681 |
| **Materials** | 1,735 | 4,016 | 14,725 | 1,194 | 1,179 | 1,452 | 5,118 | 1,165 | 1,166 | 1,165 | 1,205 | 1,690 | 1,167 | 1,329 | 1,165 |
| **Consumables** | 4,412 | 5,306 | 16,664 | 17,898 | 7,917 | 1,169 | 32,377 | 3,152 | 1,131 | 464 | 3,201 | 11,461 | 21,960 | 3,658 | 1,464 |
| **Labour** | 2,949 | 3,301 | 18,794 | 1,111 | 884 | 3,426 | 9,943 | 2,156 | 901 | 990 | 3,818 | 10,189 | 1,340 | 4,707 | 436 |
| **Other** | 1,639 | 2,582 | 12,019 | 380 | 189 | 518 | 2,949 | 397 | 59 | 231 | 1,571 | 2,770 | 208 | 1,280 | 172 |
| | **5%** | **7%** | **30%** | **6%** | **3%** | **2%** | **17%** | **2%** | **1%** | **1%** | **4%** | **10%** | **7%** | **4%** | **1%** |
| **Perfusion Factor** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Capital Charge** | 6,562 | 10,291 | 47,878 | 1,117 | 559 | 1,033 | 10,601 | 1,581 | 210 | 921 | 6,274 | 10,502 | 822 | 4,969 | 681 |
| **Materials** | 1,735 | 4,016 | 14,725 | 1,194 | 1,179 | 1,452 | 5,118 | 1,165 | 1,166 | 1,165 | 1,205 | 1,690 | 1,167 | 1,329 | 1,165 |
| **Media** | 570 | 2,852 | 13,560 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Buffer** | 0 | 0 | 0 | 30 | 15 | 3 | 3,954 | 1 | 2 | 1 | 40 | 525 | 3 | 165 | 1 |
| **Direct RM** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Bought WFI & PW** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **CIP** | 0 | 0 | 0 | 0 | 0 | 285 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **QC tests** | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 | 1,164 |
| **Consumables** | 4,412 | 5,306 | 16,664 | 17,898 | 7,917 | 1,169 | 32,377 | 3,152 | 1,131 | 464 | 3,201 | 11,461 | 21,960 | 3,658 | 1,464 |
| **Resins/MA** | 0 | 0 | 0 | 0 | 0 | 0 | 26,959 | 0 | 0 | 0 | 300 | 3,006 | 0 | 0 | 0 |
| **Bags** | 4,412 | 5,306 | 16,664 | 2,064 | 0 | 0 | 4,477 | 3,152 | 0 | 0 | 2,901 | 8,455 | 1,160 | 1,000 | 1,000 |
| **Filters** | 0 | 0 | 0 | 15,834 | 7,917 | 1,169 | 941 | 0 | 1,131 | 464 | 0 | 0 | 20,800 | 2,658 | 464 |
| **Packages** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Other** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Labour** | 2,949 | 3,301 | 18,794 | 1,111 | 884 | 3,426 | 9,943 | 2,156 | 901 | 990 | 3,818 | 10,189 | 1,340 | 4,707 | 436 |
| **Process** | 1,239 | 1,387 | 7,895 | 467 | 371 | 1,439 | 4,177 | 906 | 378 | 416 | 1,604 | 4,280 | 563 | 1,977 | 183 |
| **Quality** | 1,239 | 1,387 | 7,899 | 467 | 372 | 1,440 | 4,179 | 906 | 379 | 416 | 1,605 | 4,282 | 563 | 1,978 | 183 |
| **Indirect** | 471 | 527 | 3,000 | 177 | 141 | 547 | 1,587 | 344 | 144 | 158 | 609 | 1,627 | 214 | 751 | 70 |
| **Other** | 1,639 | 2,582 | 12,019 | 380 | 189 | 518 | 2,949 | 397 | 59 | 231 | 1,571 | 2,770 | 208 | 1,280 | 172 |
| **Insurance/other** | 341 | 534 | 2,485 | 58 | 29 | 54 | 550 | 82 | 11 | 48 | 326 | 545 | 43 | 258 | 35 |
| **Waste mgmt** | 0.99 | 1.53 | 5.53 | 32.71 | 15.33 | 1.78 | 5.82 | 2.19 | 2.19 | 0.29 | 1.71 | 7.40 | 1.98 | 0.88 | 0.71 |
| **Maintenance** | 308 | 484 | 2,251 | 53 | 26 | 49 | 498 | 74 | 10 | 43 | 295 | 494 | 39 | 234 | 32 |
| **Utilities** | 989 | 1,563 | 7,278 | 236 | 118 | 414 | 1,895 | 238 | 36 | 140 | 948 | 1,724 | 125 | 788 | 104 |
| **TOTAL (USD)** | **17,297** | **25,496** | **110,079** | **21,700** | **10,728** | **7,599** | **60,989** | **8,451** | **3,468** | **3,772** | **16,068** | **36,613** | **25,496** | **15,943** | **3,918** |
| **Total (USD/Gram normalized for the output)** | **6,562** | **10,291** | **47,878** | **1,117** | **559** | **1,033** | **10,601** | **1,581** | **210** | **921** | **6,274** | **10,502** | **822** | **4,969** | **681** |

# Appendix *(continued)*

## *C. Scenario 3 process*

### Table 10: *Scenario 3 - Process sequence*

| No | Process Stage | Unit Op Name | Conc (g/L) | Yield (%) | Duration (hr) | Adjusted Duration (hr) | Mass In (g) | Mass Out (g) | Vol In (L) | Vol Out (L) | Target Out | Capacity Out (kg/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Feed | 0.0 | | | | | | | 16.0 | | |
| 1 | Upstream | N-2 Seed | 0.0 | 0% | 184.5 | 61.5 | 0.0 | 0.0 | 16.0 | 80.0 | 0.0 | 0.0 |
| 2 | Upstream | N-1 Seed | 0.0 | 0% | 184.5 | 61.5 | 0.0 | 0.0 | 80.0 | 400.0 | 0.0 | 0.0 |
| 3 | Upstream | Production | 5.0 | 100% | 390.5 | 65.1 | 0.0 | 10,000.0 | 400.0 | 2,000.0 | 10.0 | 1,000.0 |
| 4 | Recovery | Primary depth filter | 4.3 | 90% | 2.0 | 2.0 | 10,000.0 | 9,000.0 | 2,000.0 | 2,112.0 | 9.0 | 900.0 |
| 5 | Recovery | Secondary depth filter | 3.9 | 95% | 1.7 | 1.7 | 9,000.0 | 8,550.0 | 2,112.0 | 2,168.0 | 8.6 | 855.0 |
| 6 | Purification | Filtration (0.2um) | 3.8 | 98% | 2.1 | 2.1 | 8,550.0 | 8,379.0 | 2,168.0 | 2,179.8 | 8.4 | 837.9 |
| 7 | Purification | Protein A | 15.1 | 90% | 11.6 | 27.6 | 8,379.0 | 7,541.1 | 2,179.8 | 498.8 | 7.5 | 754.1 |
| 8 | Purification | Virus Inactivation | 14.5 | 98% | 4.5 | 4.5 | 7,541.1 | 7,390.3 | 498.8 | 508.8 | 7.4 | 739.0 |
| **9** | **Purification** | **3M™ Polisher ST** | **13.2** | **99%** | **0.8** | **0.8** | **7,390.3** | **7,316.4** | **508.8** | **556.2** | **7.3** | **731.6** |
| 10 | Purification | IEX Bind & Elute | 14.9 | 95% | 8.8 | 8.8 | 7,316.4 | 6,950.6 | 556.2 | 467.6 | 7.0 | 695.1 |
| 11 | Purification | Viral Filtration | 14.3 | 98% | 3.0 | 3.0 | 6,950.6 | 6,811.5 | 467.6 | 477.6 | 6.8 | 681.2 |
| 12 | Purification | UF/DF | 50.0 | 98% | 8.3 | 8.3 | 6,811.5 | 6,675.3 | 477.6 | 133.5 | 6.7 | 667.5 |
| 13 | Purification | Filtration (0.2um) | 47.6 | 98% | 0.9 | 0.9 | 6,675.3 | 6,541.8 | 133.5 | 137.4 | 6.5 | 654.2 |

### Table 11: *Scenario 3 - cost of goods breakdown (USD per batch)*

| | N-2 Seed | N-1 Seed | Production | Primary depth filter | Secondary depth filter | Filtration (0,2um) | Protein A | Virus Inactivation | 3M™ Polisher ST | IEX Bind & Elute | Viral Filtration | UF/DF | Filtration (0,2um) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | **9** | 10 | 11 | 12 | 13 |
| **Equipment (Total)** | 718,521 | 1,126,783 | 5,242,392 | 121,927 | 60,963 | 113,097 | 1,148,389 | 169,201 | **672,498** | 1,137,596 | 89,930 | 545,788 | 74,518 |
| **Capital** | 6,475 | 10,154 | 47,240 | 1,099 | 549 | 1,019 | 10,348 | 1,525 | **6,060** | 10,251 | 810 | 4,918 | 671 |
| **Materials** | 1,914 | 4,195 | 14,904 | 1,373 | 1,358 | 1,631 | 5,297 | 1,344 | **1,423** | 1,869 | 1,346 | 1,520 | 1,344 |
| **Consumables** | 4,412 | 5,306 | 16,664 | 17,898 | 7,917 | 1,169 | 32,377 | 2,963 | **6,753** | 11,461 | 21,960 | 3,658 | 1,464 |
| **Labour** | 2,947 | 3,299 | 18,781 | 1,101 | 879 | 3,423 | 9,937 | 2,839 | **1,407** | 10,187 | 1,338 | 4,805 | 412 |
| **Other** | 1,618 | 2,549 | 11,862 | 375 | 187 | 515 | 2,887 | 383 | **1,520** | 2,708 | 206 | 1,270 | 169 |
| | **5%** | **7%** | **30%** | **6%** | **3%** | **2%** | **17%** | **2%** | **5%** | **10%** | **7%** | **4%** | **1%** |
| **Perfusion Factor** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **1** | 1 | 1 | 1 | 1 |
| **Capital Charge** | 6,475 | 10,154 | 47,240 | 1,099 | 549 | 1,019 | 10,348 | 1,525 | **6,060** | 10,251 | 810 | 4,918 | 671 |
| **Materials** | 1,914 | 4,195 | 14,904 | 1,373 | 1,358 | 1,631 | 5,297 | 1,344 | **1,423** | 1,869 | 1,346 | 1,520 | 1,344 |
| **Media** | 570 | 2,852 | 13,560 | 0 | 0 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | 0 |
| **Buffer** | 0 | 0 | 0 | 30 | 15 | 3 | 3,954 | 1 | **79** | 525 | 3 | 177 | 1 |
| **Direct RM** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | 0 |
| **Bought WFI & PW** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | 0 |
| **CIP** | 0 | 0 | 0 | 0 | 0 | 285 | 0 | 0 | **0** | 0 | 0 | 0 | 0 |
| **QC tests** | 1,343 | 1,343 | 1,343 | 1,343 | 1,343 | 1,343 | 1,343 | 1,343 | **1,343** | 1,343 | 1,343 | 1,343 | 1,343 |
| **Consumables** | 4,412 | 5,306 | 16,664 | 17,898 | 7,917 | 1,169 | 32,377 | 2,963 | **6,753** | 11,461 | 21,960 | 3,658 | 1,464 |
| **Resins/MA** | 0 | 0 | 0 | 0 | 0 | 0 | 26,959 | 0 | **5,500** | 3,006 | 0 | 0 | 0 |
| **Bags** | 4,412 | 5,306 | 16,664 | 2,064 | 0 | 0 | 4,477 | 2,963 | **1,253** | 8,455 | 1,160 | 1,000 | 1,000 |
| **Filters** | 0 | 0 | 0 | 15,834 | 7,917 | 1,169 | 941 | 0 | **0** | 0 | 20,800 | 2,658 | 464 |
| **Packages** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | 0 |
| **Other** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | 0 |
| **Labour** | 2,947 | 3,299 | 18,781 | 1,101 | 879 | 3,423 | 9,937 | 2,839 | **1,407** | 10,187 | 1,338 | 4,805 | 412 |
| **Process** | 1,226 | 1,373 | 7,816 | 458 | 366 | 1,425 | 4,136 | 1,182 | **585** | 4,240 | 557 | 2,000 | 171 |
| **Quality** | 1,254 | 1,404 | 7,995 | 469 | 374 | 1,457 | 4,230 | 1,209 | **599** | 4,336 | 570 | 2,045 | 175 |
| **Indirect** | 466 | 522 | 2,970 | 174 | 139 | 541 | 1,572 | 449 | **222** | 1,611 | 212 | 760 | 65 |
| **Other** | 1,618 | 2,549 | 11,862 | 375 | 187 | 515 | 2,887 | 383 | **1,520** | 2,708 | 206 | 1,270 | 169 |
| **Insurance/other** | 336 | 527 | 2,454 | 57 | 29 | 53 | 538 | 79 | **315** | 533 | 42 | 255 | 35 |
| **Waste mgmt** | 0.99 | 1.53 | 5.53 | 32.71 | 15.33 | 1.78 | 5.82 | 2.19 | **3.02** | 7.40 | 1.98 | 0.89 | 0.71 |
| **Maintenance** | 304 | 477 | 2,220 | 52 | 26 | 48 | 486 | 72 | **285** | 482 | 38 | 231 | 32 |
| **Utilities** | 976 | 1,542 | 7,182 | 234 | 117 | 412 | 1,857 | 230 | **918** | 1,686 | 123 | 783 | 102 |
| **TOTAL (USD)** | **17,365** | **25,502** | **109,451** | **21,846** | **10,890** | **7,757** | **60,846** | **9,054** | **17,163** | **36,476** | **25,660** | **16,171** | **4,061** |
| **Total (USD/Gram normalized for the output)** | **2.7** | **3.9** | **16.7** | **3.3** | **1.7** | **1.2** | **9.3** | **1.4** | **2.6** | **5.6** | **3.9** | **2.5** | **0.6** |

**Intended Use:** 3M™ Polisher ST is a single-use filter product intended for use in biopharmaceutical processing applications of aqueous based pharmaceuticals (drugs) and vaccines in accordance with the product instructions and specifications, and cGMP requirements, where applicable.

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