

# ***Application of DMAIC Methodology to Improve the Utilization of an Industrial Glassware Washer System in a Biopharmaceutical Industry***

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**Abstract** — *This article describe how the problem solving approach of Define, Measure, Analyze, Implement and Control (DMAIC) is applied to increase the utilization of an industrial glassware washer system in a Biopharmaceutical Industry. The application of this methodology results in a deep understanding of the cleaning process. Sources of variation were identified and a root cause analysis conducted allows for the identification of potential solutions as well as selection and implementation of improvements. The implementation of improvements in the control phase reflect reductions in the amount of cleaning loads required to satisfy manufacturing needs on a weekly basis, reducing in 40% the amounts of loads, increasing by 20% the utilization of the cleaning system and providing tools to the support area staff that will allow them to have a better understanding of the logistic involved along the cleaning process.*

**Key Terms** — *DMAIC methodology, cleaning system utilization.*

## **INTRODUCTION**

Operational excellence is the north that drives the most competitive industries over the world with the mission of deliver results in the most competitive and cost effective environment.

This leading human therapeutic industry in biotechnology, for over 15 years has been focused on its vision of serve every patient every time. It has been pioneer in the development of novel products based in advances of recombinant DNA and molecular biology. Its product helps millions of people around the world to fight cancer, kidney disease, rheumatoid arthritis and other serious illness. For the past year this Biopharmaceutical

Industry in Puerto Rico has embedded operational excellence and making it a new way of doing business that allows the identification and implementation of improvements for a competitive edge.

## **BACKGROUND**

Component Preparation Area is a support area of one of the Bulk Manufacturing Plant at this Company. This Bulk Plant manufactures two products: Product A and Product B. This area support the cleaning and sanitization of miscellaneous equipment used for the manufacturing activities of products A and B. This miscellaneous equipments are small parts such as manual valves, end caps, jumpers, deep tubes, pitchers graduated cylinders among others. Over seven hundred miscellaneous components are processed and replenished to manufacturing areas on a weekly basis.

Soiled equipment that comes from manufacturing activities is manually pretreated with a cleaning solution prior being processed through a validated cleaning cycle. According to reference [1], in a bulk biopharmaceutical facility cleaning validation is the process of providing documented evidence that the cleaning method employed within a facility consistently controls potential carryover of product, cleaning agent and extraneous material into subsequent product to a level which is below predetermined levels. As regulatory requirements all cleaning processes in a biopharmaceutical industry has to be in a validated state.

Cleaning activities take place in a glassware washer system or in a clean out of place bath. The Reliance Pharmaceutical glassware washer system

consists of a chamber where the equipment is cleaned. This chamber has several inlets and outlets for the addition of chemicals, water and air required for the cleaning cycle. The chamber accommodates different carts designed for the processing of equipment considering its geometric configuration. The cart attaches to a manifold located at the bottom of the chamber. The three carts available for equipment processing have the following characteristics described by Reference [2]:

- M-9 Cart (M9): This Cart can accommodate up to 9 components per load, mainly carboys and graduated cylinders.
- Multipurpose Cart (MP): This cart has multiple accessories that allow the processing of up to 33 smaller components per load. Some of the equipments that can be processed in this cart are 5L Pitchers or glass bottles, 1L graduated cylinders, squirt bottles, carboy and bottle caps.
- General Purpose Cart (GP): This cart is used to process large components such as 180L kettles and lids. This cart accommodate up to four components per load.

Each of the three carts has a predefined validated load configuration in which the equipments can be arranged for cleaning. Product A have 3 different loads configurations and Product B have another 3 different loads configurations, which represent a total of 6 different loads configuration for the processing of the equipment in this cleaning system. These loads have been established based on the following characteristics:

- Material of Construction: glass, plastic or stainless steel
- Return Rate: based on the process step that the inventory is required
- Surface Area: the surface area of the pre-defined load must not exceed the surface area of the validated worst case load)
- Washer Cart Type: cart that can accommodate the inventory for processing according to predetermined configuration.

The utilization of the system can be determined based in the amount of inventory processed from

the maximum amount of equipment that can be processed for each configured load. Since there is no validated method for cleaning of Product A and B in the same loads, segregation between products has to be maintained. This limitation doesn't allow that equipment from Product A to be cleaned in the same loads as equipment of Product B.

Cleaning cycles of these cleaning systems requires several chemical solutions recirculation's and rinses in other to ensure acceptance of quality requirements for a successful cleaning. For each load processed the system consumes 1750L of Purified Water and 400L of Water for Injection.

The processing of the inventory through the glassware washer is performed based on the manufacturing schedule. On a weekly basis and on a manufacturing run rate of one lot per week for each of the two products, 27 loads are scheduled.

Once the manufacturing activities conclude the small equipment that supports the manufacturing processes are labeled as dirty. The date and time the components are declared as dirty is registered in that label. By that time the component has a validated dirty holding time that must not be exceeded for pre-treatment and cleaning, otherwise a deviation must be reported. Product A has 48 hours to be cleaned through required cleaning system while Product B has 50 hours.

The objective of this design project is to optimize the utilization of the glassware Washer System in the Component Preparation area that will allow:

- A full understanding of the return of dirty inventory processed.
- Reduction of 20% in the amount of loads required for processing the dirty inventory that returns from Manufacturing activities of Product A, and Product B.
- Reduction of 20% in the utilization of Purified Water and Water for injection.

### **Research Contribution**

The implementation of this project will bring to this Support Area and to the Company a new way of doing business in a most cost effective way. This

will also increase its competitive advantage in the marketplace:

- Enhance quality
- Reduce non value added time
- Increasing the labor utilization
- Develop staff by developing skills that allows them increase their efficiency and get better understanding of the cleaning activities at their working environment.
- Promote a culture of continuous improvement to the staff that works in the support area and manufacturing areas.

In an effort to address the several opportunities identified Six Sigma tools will be considered for the development of this project.

### Six Sigma

Reference [3] defines Six Sigma as a sophisticated problem solving approach for driving, achieving and sustaining improvement within an organization. As with the lean concepts its roots are traced by the nineteenth –century crafts-man, seeking for opportunities to reduce the wasted time and increase the quality of their products.

The ultimate goal with the application of Six Sigma is to be able to improve process by controlling and understanding variation which leads to reductions of defects or mistakes to zero.

Depending on the complexity of the problem under analysis Six Sigma projects typically takes from 1 to 3 months. Some of the benefits of implementing six sigma in a process are:

- Increase in customer satisfaction
- Increase in productivity
- Reduction of costs and defects
- Decision making process based in facts and not speculations

Among the various approaches within Six Sigma the most common methodology for problem solving is known as the Define-Measure-Analyze-Improve-Control (DMAIC) approach. Usually the DMAIC approach is applied to problems within an existing steady state process. DMAIC target the resolution of issues of defects or failures, excess

cost or time, and deterioration. Originally the application of DMAIC addresses improvement in productivity, financial, quality and time, from which cost prevails the financial aspects. Lately the approach has been mostly employed in revenues and growth initiatives.

The DMAIC methodology is enclosed in a five process step structure which are:

- **Define:** This step encloses the definition and scope of the project. This step includes the description of the problem, how long the problem has been identification of the customer, project goals and timeframe for completion.
- **Measure:** – The current performance of the process is measured. In this step available data from the current performance is gathered and summarized, providing a story that describes the problem.
- **Analyze:** Qualitative and statistical analysis is employed to isolate the problem. Test Hypothesis is formulated regarding the root cause of the problem.
- **Improve:** The problem is improved by the selection of a solution considering the findings in the previous step. Improvements are employed attempting to directly address the root cause. In this step potential solutions may be evaluated prioritized and tested to see if the problem is eliminated.
- **Control:** Once the solution has resolved the problem the improvements must be standardized and sustained over time.

## METHODOLOGY

For the development of this project the Six Sigma DMAIC methodology was employed. The five step approach was applied as follow:

### Definition

The definition step was applied to identify the problem statement scope and timeline for project implementation. Also the development of a Process map and definition of critical parameters was

established as part of the definition process. The definition of critical parameters was accomplished by gathering the voice of the customer with the execution of a brainstorming exercise. This exercise was performed with the staff that works in the Support area.

### **Measure**

The measuring step was executed by gathering for two weeks data from the cleaning processing activities of the glassware washer system. For each load processed for manufacturing purposes the following data was identified as data to be gathered: Product from which the equipment comes, load configuration used (cart used for each load processed), actual dirty holding time, and amount of equipment processed per pre-defined load.

### **Analyze**

The analysis step was employed to study data collected from the measuring step. The data and the cleaning process were evaluated by the application of statistical analysis and graphical methods. Statistical analysis was used to establish average amount of loads processed for each product (A or B), overall utilization and utilization per washer system cart and average weekly water consumption. Also Bar charts were used to analyze the relationship between actual dirty holding times with the utilization percentage of each load processed.

A root cause analysis was performed with the application of the problem solving tool cause and effect also known as fish bone analysis.

### **Improve**

The improve step was implemented to define and evaluate potential solutions that can increase the utilization of the cleaning system, selection and implementation of potential solutions. The identification of potential solution was performed with the application of a brainstorming exercise. From the potential solution identified, a prioritization exercise was conducted to select potential solutions for implementation.

### **Control**

The last step of the methodology was developed by implementation of the improvements and monitoring of the glassware washer system performance. Performance metrics was defined to estimate effectiveness of improvements after the implementation. Training was facilitated to impacted staff. This includes staff from the support areas and from the manufacturing areas that received the equipments.

## **RESULTS**

After implementation of the DMAIC Methodology the following results were obtained:

### **Define**

In the define step, the project charter was developed to establish the scope of the project, select and inform the employees that will be working in the project and to establish the implementation timeline. Other activity performed under the definition step was the identification of common causes of variation for the cleaning system utilization. This activity was performed with staff of the support area in order to obtain the voice of the customer. The following were identified as the Critical inputs:

- Planning of cleaning activities
- Loads configuration
- System processing capacity/load

For each critical input, the common causes of variation were identified. Elements for process planning are: manufacturing production run rate, return of dirty inventory, reprocessing of expired inventory, and dirty holding time. Elements for loads configurations were identified as: validation approach, and return of inventory. Elements that cause variation to system processing capacity are: washer carts utilization and cleaning validation approach.

### **Measure**

The measuring step was executed in a two week timeline. Data from the cleaning process was

gathered for the equipment processed of Product A and B. The following table represents a sample of information gathered from the cleaning process of equipment from Product A the first week of measuring.

**Table 1**  
**Data Gathered for Equipment process for Product A Week 1**

Date	Cart Type	ADHT (Hrs)	Qty of Equipment Processed
2/23/09	MP	4	17
2/23/09	M9	8	5
2/23/09	GP	11	2
2/24/09	M9	5	6
2/24/09	M9	6	1
2/25/09	MP	21	8
2/25/09	MP	2	7
2/25/09	MP	7	11
2/25/09	GP	7	3
2/26/09	M9	23	3
2/26/09	MP	15	12
2/27/09	M9	14	3
2/27/09	MP	12	12
2/27/09	MP	1	3

The water consumption was calculated considering the amount of water that the system load for each rinse or recirculation steps of the cleaning process. Another data gathered was the scheduled loads of inventory and the actual loads processed. This one was gathered to analyze the effectiveness of the scheduling system in this support area.

### Analyze

The following table summarizes the results after the analysis of the data from cleaning processing activities:

**Table 2**  
**Cleaning System Utilization Performance Analysis**

Product	Average Loads Processed/Week	Average ADHT (hrs)	Average Utilization% / Cart		
			M9	GP	MP
A	14	12	50.6	53.1	31.3
B	13	12	48.1	28.1	32.5

For typical weeks in which one lot of each product is processed, averages of 27 loads are processed. In terms of the actual dirty hold time, an

average of 12 hours is considered prior processing the loads of a total of 48-50 hours available. The utilization percentage was determined for each load processed and results were analyzed per each of the three system accessories. Utilization percentage ranges between 28.1 and 50.6. In addition graphical methods were considered for analysis of cleaning process and cleaning system utilization.

Analyzing more deeply the system accessories it was noticed that the MP cart is has limitation in the maximum amount of certain inventory that can only be processed in three places. Due to this limitation multiple loads of this accessory has to be processed in order to process all the inventory required.

Another finding from the analysis of the amount of loads processed was that there are some loads processed with low utilization and low actual dirty hold time. Since the support area staff can't anticipate the return of inventory, inefficient loads were processed.

Schedule Adherence and Water Consumption Analysis was also made from the data gathered. In terms of the amount of loads schedules versus the amount of loads processed the re is no significant variation. However significant variation was observed in the detail daily schedule in witch the scheduled loads does not match the loads processed. In terms of water consumption for the total of loads process per week 58,050 liters of water are consumed.

After the analysis of the data, a root cause analysis was developed by applying the cause and effect technique. From this exercise fourteen causes were identified that causes variation in the processing of equipment. Detail of each finding can be described in the Cause and diagram of Figure1.

### Improve

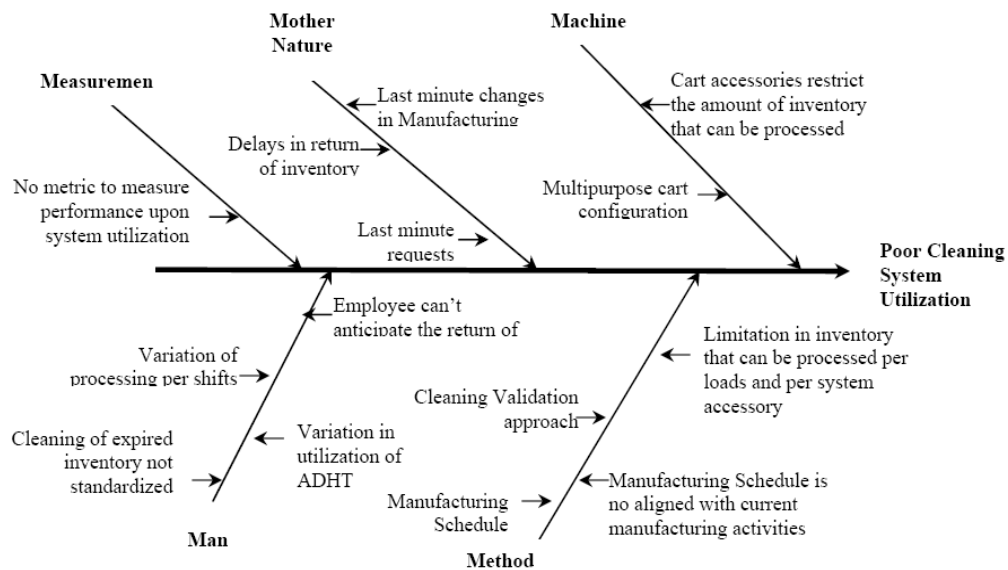
In the improve step a brainstorming was perform with staff on the support area identifying solution for the potential root causes identified From this brainstorming activity thirteen potential solutions were identified. These solutions were evaluated using a prioritization matrix to select the

potential solutions with most feasibility for implementation. From the proposed solutions five requires mayor investments and impact the validated state of the cleaning process. Due to this limitation the team agrees in implement the following eight solutions which require a minor investment. The other five solutions were kept for future implementation.

- Development of a logistic tool that helps the employees anticipates the inventory that will be receiving for processing. This tool may contain detail description of the inventory that is replenished by manufacturing areas, quantities used and date the inventory is requested. In addition the tool should specify the accessory in which it can be cleaned in order to optimize the utilization of the cleaning systems. With the development of this tool is expected that the support area staff can anticipate the return of inventory and increase the utilization of the cleaning systems in combination with the utilization of the Actual Dirty Hold Time to trigger the processing of components. From the development of this tool it was establish that the weekly amount of loads that may be required to process all inventory from manufacturing activities of

Product A and Product B are: 9 and 8 loads respectively. This represents a theoretical reduction in loads between 36% and 38 % in the amount of loads required per lot.

- Standardized the practice of wait up to 80% of the maximum dirty holding time for processing of the inventory. After evaluation of the proposal with associate's agreement was made for the second shift to wait up to 29 hours. This to avoid risk of expiration of MDHT.
- Standardize the processing of expired equipment. Expired equipment will be the last option for processing under normal operating conditions. With the implementation of these initiatives, the utilization of the systems will be driven by inventory that returns from manufacturing activities and no from excess of inventory that is typically cleaned and not used for manufacturing purposes.
- Improve communication channels between manufacturing areas and the support area. The implementation of this initiative will ensure that inventory is returned by the time the manufacturing activities conclude.
- Standardize the practice of use shift change internal reports to communicate inventory issues (defective inventory, etc.).



**Figure 1**  
Cause and Effect Diagram

- Establish metrics of performance and discuss them with the staff. The metrics of performance will give visibility to the associates of how they are performing against what is expected.
- Plan cleaning activities out of Scheduling

To ensure sustainability of the implementation process a transition plan was developed. This document contained an organized description of all the initiatives that will be conducted, owner of each initiative and critical parameters that will ensure the desired project results.

### Control

After the implementation of improvements, training was facilitated to employees from the support area. This training explain the utilization of the new tool introduced to the area that will help staff anticipate the return of inventory from manufacturing areas, the standardization in the utilization of the ADHT, modifications in the planning of processing that will not be triggered by manufacturing schedule and also the new monitoring activity and critical parameters. In addition training to manufacturing areas was provided explaining the new strategy of cleaning system utilization and how they can contribute to a better utilization of the cleaning system.

Critical parameters to be monitored were the utilization percentage, and the actual dirty hold time for each load processed.

After implementation of the initiatives and the delivery of training to the impacted staff the following results were obtained.

**Table 3**  
**Cleaning System Utilization Performance Analysis After Implementation of Improvements**

Product	Average Loads Processed/Week	Average ADHT (hrs)	Average Utilization% / Cart		
			M9	GP	MP
A	9	29	68.5	68.8	45.1
B	7	30	70.4	25	56.6

Reduction in 40% in the amount of loads processed of product A and B. This represents a saving in water consumption of 22575 liters weekly. The utilization of cleaning systems increased. In terms of actual dirty holds time utilization, it was observed an increase between 233 to 250% in the utilization of this, contributing to an average increase on 15% in the utilization of the cleaning systems.

### CONCLUSIONS

The application of the DMAIC methodology for the optimization of the cleaning system utilization has been successful in the reduction of 40% the amount of loads required for processing equipment. Also a 39% reduction of water consumption has been achieved from the implementation of this project.

The development of tools that enhance the knowledge of the staff and understanding of its process, and identification and reduction of sources of variability within the cleaning processes has been able to increase by 15% the utilization of the cleaning system.

All objectives that motivated the implementation of this project have been successfully accomplished. However the following recommendations are provided in order to increase the utilization of cleaning systems and reduction of water consumption used for cleaning processes:

Modification of loads configurations that aligned them to the expected equipment that returns from manufacturing activities. This inactive may impact the validated state of the cleaning process.

Extend the validated dirty holding time. Since this triggers the processing of equipment it will allow for additional optimization of the systems utilization and reduction in the amount of cleaning loads required.

Consolidate the cleaning of equipments of Product A and B. This consolidation will

increase the utilization of the system and reduce the weekly water consumption

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