Potable Water Quality Improvement in a Water Filtration Plant Facility

Dori A. Hernández-Rodríguez
Manufacturing Engineering
Carlos González, Ph.D.
Manufacturing Engineering
Polytechnic University of Puerto Rico

Abstract — *The processes used for treatment in water plants depend on the quality of the source and the desired quality of the water. The chemicals selected for the treatment depend on the effectiveness to obtain the desired reaction and cost Pure water could be contaminated by the air and the ground. The impurities can be organic such as fatty acids, inorganic carbohydrates and/or like toxic metals, solid particulate like clays and sediments or microorganisms like bacteria and virus. The project is focused in the quality of manufactured water from Puerto Rico Aqueduct and Sewage Authority (PRASA). The existing water treatment process considered several parameters that defined water quality but does not relates it with administrative procedures. Specific parameters such as Manganese (Mn) concentration and Turbidity behavior were studied in order to preform causes analysis. The implementation of improvement techniques in the Water Filtration Plant (WTP) were evaluated and approved by managers.*

Key Terms — *Chemical Dose, Manganese Concentration, Operational Practices, Turbidity Values.*

INTRODUCTION

During the past years, home-water uses have been more regulated and as the demand have increased substantially, the treatment process have been also, more important and considered to be one of the most regulated process in terms of public health by the Department of Health of Puerto Rico. Also the Puerto Rico Aqueduct and Sewage Authority (PRASA) are regulated by the Environmental Protection Agency (EPA). EPA regulates the water quality that is distributed around all water bodies [1]. Recently, the Department of Health of Puerto Rico has created a program that includes PRASA as one of their targets. In this program the water distribution is regulated five (5) times stronger than the past two (2) years. In order to follow and be in compliance with the Clean Water Act, water quality analysis is performed daily and –hourly- by all regional Water Treatment Plant personnel. On the other hand, the most important consideration in the design of a water plant is to provide flexibility where there is a possibility of changing the point of application of chemicals, to change them and to have space for the construction of additional units of pre-processing. Also, resulting values of specific health-affecting parameters are sent to the Department of Health of Puerto Rico daily. They track everyday each Water Treatment Plan situation and develop a public report for all consumers.

DESCRIPTION

Most of the Water Treatment Plant (WTP) Facilities do not follow a guide for a good practice in the manufacturing processes nor quality guidelines. Therefore, fundamental steps are ignored and the value definition is not properly stated such as non-constant water quality, non-constant water service, queue steps in the manufacturing process, loss of money and political influence in this service sector [2].

Since quality guidelines are not used and water manufacturing practices are not well achieved, it is possible to infer that the process is not flowing properly and also, that the water quality is being directly affected.

Water Treatment Plant Facility

Aeration promotes the establishment of equilibrium between dissolved, volatile constituents in the water and the constituents in the air to which the water is exposed. The function of aeration is to speed up this natural process (see Figure 1).

Figure 1
Aeration Oscillation Mechanism

The coagulation is the first step to destabilize the particle's charges. Coagulants with charges opposite to those of the suspended solids are added to the water to neutralize the negative charges on dispersed solids [3]. Then the flocculation occurs in a slow mixing stage to increase and agglomerate the particle to form flocs. The sedimentation refers to the process where the solid fall by gravity. The particles settled out as sediment and are removed from the water supply. Inlets of the tank are designed to distribute water to uniform velocities. Sedimentation tanks are used to settle out the floc before going to the filters (see Figure 2).

Figure 2
Sedimentation Basin

Filtration uses a porous media to remove all remaining particles from the water. The process clarifies water and enhances the effectiveness of disinfection. The process removes organic and inorganic compounds contained in water and reduces polluting agents.

The granulated media used in this process should not react with water components, and should be insoluble in water and permeable. The media frequently used in this process is sand. In Figure 2, the media is visible and represent the Filters used in the WFP. Disinfection ensures that potentially harmful organisms and pathogenic bacteria are killed before water is distributed to homes and businesses using chlorination. Water is disinfected but never completely sterilized in the water treatment process [4]. Water clarification process is not one process but the combination of different processes. Large suspended solids get settle down by gravity. For non-settle able material removal is done through coagulation, sedimentation and flocculation. The chemical treatment process is based on that the water previously aerated, goes directly to the mixing chamber in which high mixing between coagulant (polymer) and raw -aerated- water is performed. The chemical injection is based on two rotary gear pumps and it is auto controlled by electrical signal sent from the inflow instrument that measures water turbidity. Gas chlorine injection occurs through vacuum pumps and is manually controlled by the plant's operator. Chlorine is injected to the post filter water.

SIX SIGMA THINKING

Historical data log of quality parameters should be analyzed and therefore, implemented as a basis for the new project initiatives. Historical data may include: High and low turbidity values (see Table 1), pH values variance, Alkalinity values, Chlorine, Manganese (see Table 2), Iron and Total Organic Carbon concentration. Once the method is defined (in terms of evaluation), resources are identified.

Table 1
Turbidity Summary

Nephelometric Turbidity Units (NTU)				
Month	Raw Water	Settled Water	Filtered Water	Distributed Water
Aug-12	5.110	1.218	0.154	0.287
Sep-12	36.493	1.033	0.222	0.531
Oct-12	71.380	2.436	0.123	0.270
Nov-12	31.757	2.090	0.098	0.109
Dec-12	10.771	1.141	0.108	0.128
Jan-13	32.047	0.598	0.107	0.092

Compliance parameter should not be above 0.05mg/L from distributed water [5]. It should be related with pH, alkalinity and corrosion control in the plant.

Table 2
Manganese Concentration Summary

Manganese Concentration (mg/L)				
Month	Raw Water	Settled Water	Filtered Water	Distributed Water
Aug-12	0.288	0.264	0.039	0.020
Sep-12	0.290	0.270	0.040	0.016
Oct-12	0.226	0.222	0.056	0.079
Nov-12	0.417	0.402	0.021	0.007
Dec-12	0.230	0.193	0.067	0.027
Jan-13	0.139	0.100	0.039	0.032

The analysis performed is categorized in both water quality measured by manganese concentration & turbidity and chemical product consumption in terms of money. Several variables such as raw values were considered (see Figure 3).

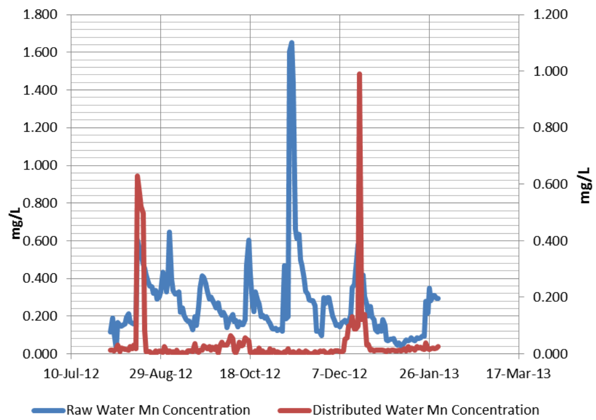

Figure 3
Raw Water Turbidity vs. Distributed Water

For high Manganese issues a root cause analysis was performed (see Figure 3). The analyzed data was collected under certain atmospheric conditions and several administrative changes.

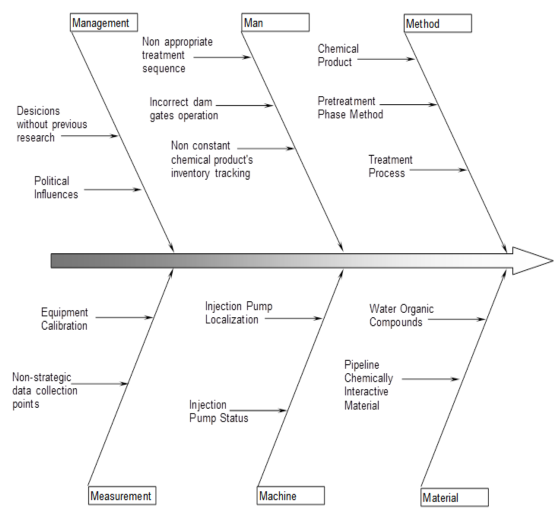

Figure 4
Root Cause Analysis for High Manganese

Also, a matrix plot was performed in order to establish relations (see Figure 4). Usually, filtrated water tends to be inside the compliance parameters when distributed water is not. This is because the flushing system procedures and also, the basin locations. Filtration system is located before the distribution tank.

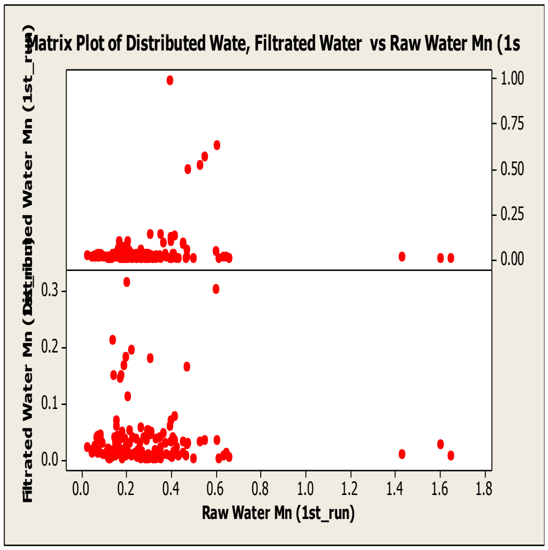

Figure 5
Matrix Plot for Filtrated and Distributed Water

Turbidity sampling was performed during the established period of time and its behavior was not enough variable to determine its appropriate yield (see Figure 6).

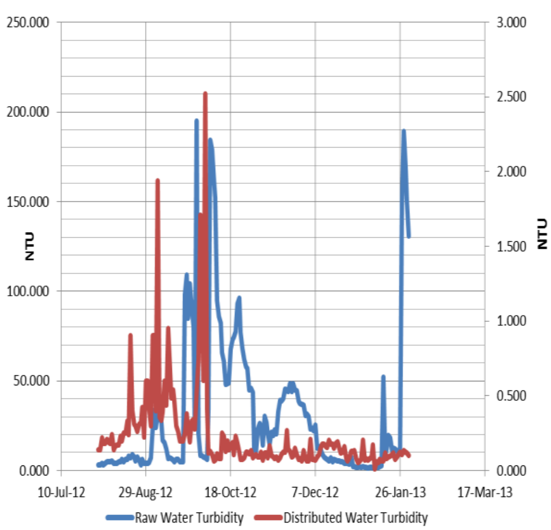

Figure 6
Turbidity Behavior

In order to organized and determine potential causes of high turbidity values, a root cause analysis was performed (see Figure 7).

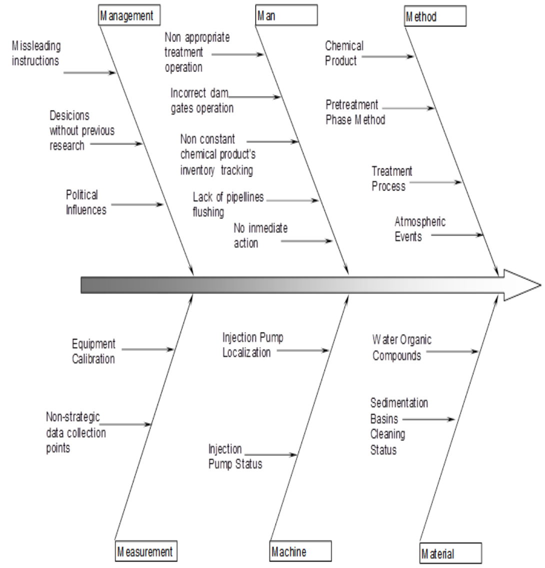

Figure 7
Root Cause Analysis for High Turbidity

Once the causes were identified, a dot plot was developed in order to understand the distribution of turbidity data (see Figure 8).

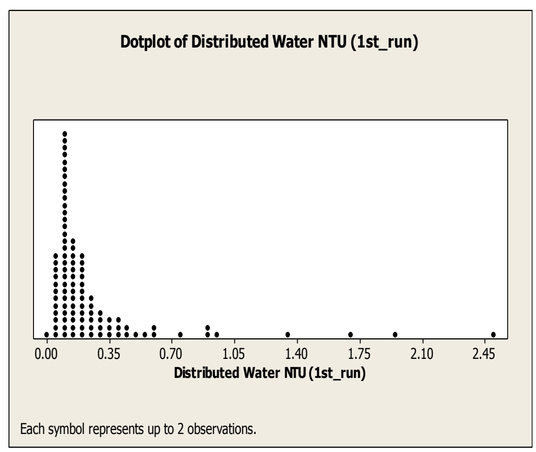

Figure 8
Dot Plot Analysis for Turbidity Values Distribution Basin

Turbidity data distribution was not normal and therefore, quality aspects are not well arranged. Several numbers were found to be outliers and the primary cause was considered to be operational for. Turbidity is the most common evaluated parameter and a powerful tool to determine (as fast as possible) an upcoming event. It should be related to the chemical dose, Manganese and Iron concentration. The improvement phase is based on identifying potential solutions, selecting solutions to implement, operational strategies, change of culture, implementing improvements, evaluating improvements, demonstrating solutions. Potential solutions are categorized in Equipment and Plant Status, Operational Procedures and Sampling Methods (see Figure 9).

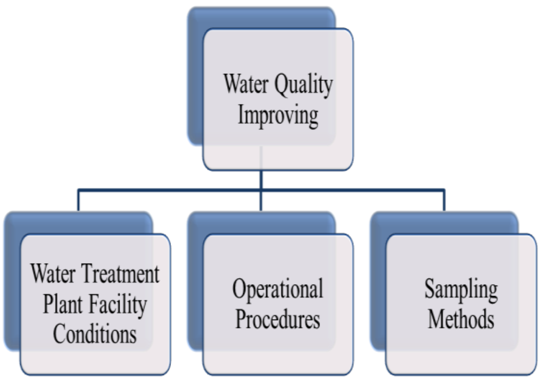

Figure 9
Breakdown Structure for Improvements

The water treatment plant facility category is defined by: raw water piping status, basin cleaning, and mechanical equipment such as rapid mixers, flocculators, sump pumps, chemical pumps, infrastructure and hygiene. Operational procedures are divided in: pretreatment dose, polymer injection amount, polymer injection point, chlorine injection method, settled time, decision making skills and personnel culture. In sampling methods category, the differences between operators and technician sampling is wide. Equipment calibration and tolerance validation is highly important. The vital and possible (to be immediate edited) changes are based on the pretreatment dose phase, polymer injection point, operational flow and personnel culture. In order to improve the pretreatment dose phase, it is required to implement the $NaMnO_4$ dose protocol and rebuild the pipeline system with the appropriate material (THEFLON). Polymer injection point is a fundamental strategy for a good chemical treat of water. If the injection point is not located properly, the facility would not make potable water. The previous injection point was located at the flocculation basin. In order to improve flocs formation and enhance the coagulation process, the appropriate location would be in the mixing chamber. The change of injection point took place at the plant's operator control room and was analyzed as a pilot system. Demonstration at low scale in the laboratory facility was required. The laboratory technique is named as Jar Test and consists of a jar that represents the sedimentation basins followed by continued mixing with atomized blades. Flocculation basins should be operating in optimum conditions since the chemical product will not interact with charged water particles and coagulate. Flocculation basins need to operate properly and the purchase order of it is already worked (see Figure 10).

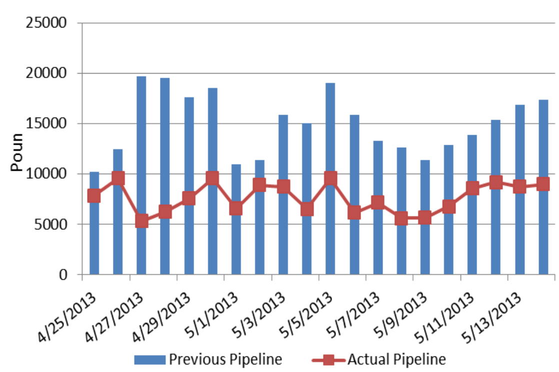

Figure 10
Chemical consumption changes

Other important issue is the hygiene. Animals are strictly prohibited by the Department of Health. Animals could result in thrialometanes (THM's) concentration in water. These organisms are carcinogenic and very difficult to treat once in the water. Control charts have been used to ensure that the improvements implementations gave well results (see Figure 11).

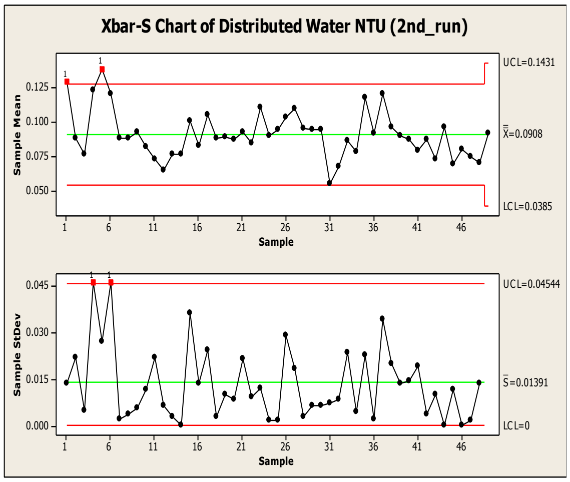

Figure 11
Control Chart for Distributed Water Turbidity

Chemical Analysis could result in doubt because of the sampling method. The lack of credibility is a factor that might be checked. Either in line sampling or grab sampling methods must be evaluated. Moreover, equipment calibration should be strictly monitored (see Figure 12).

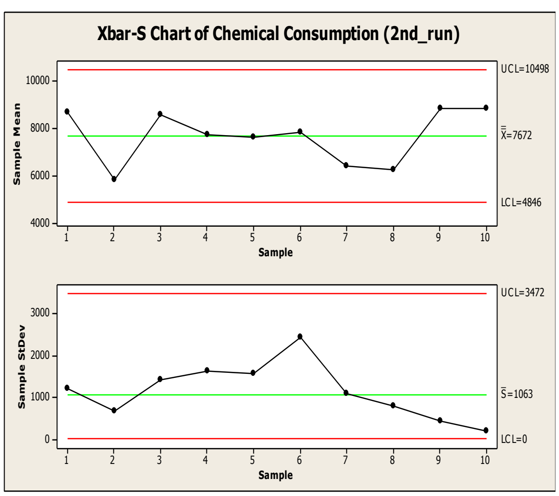

Figure 12
Controlled Chemical Product Consumption

Conclusion and Recommendations

A number of parameters that influence high turbidity and manganese behavior have been identified, but there is a consensus of which of these are of the greatest concern in water treatment strategy. This work has introduced chemicals uses and personnel approach as a criterion. The objectives of lowering manganese concentration and turbidity are related easily with the lack of administrative guidelines and prioritization concerns. The Health Department of Puerto Rico and Federal EPA regulate the quality of the potable water, the sludge and water discharge, under the Safe Drinking Water Act. Using the previous information, the water quality depends on manage and strategic use of chemical products for the treatment process. Actual process resulted in a 95% not controlled nor prioritized. Also, personnel culture and political influences contributes 66% and 89% respectively in water quality distribution system for the Metro Area. Concerning to the chemical products uses, an increase of 19% compliance in water quality and $21,000/month savings resulted even when the consumption is not 100% controlled. New practices follow the idea of linkage between chemical product (GC-8791) and operational procedures [6]. Several factors are considered to be a limitation but data analysis and research is the key to maintain controlled water quality parameters. Also, manager's perception and support is required for such changes. The recommendations for the operational changes include: the polymer injection must be automated to know the correct doses of chemical for entire system. Initial implementation based on operational process and sampling methods was completed successfully. The distributed water Mn concentration resulted in a 12% improve with a mean of 0.037 mg/L while turbidity vales resulted in a 29% improve with a mean of 0.09 NTU. A continuous chemical dose analysis is required at the WFP in order to reduce contaminants in the water, prevent THM's, prevent periodic sampling of the sludge for a least a year to determine the correlations between noncompliance events and compliance atmosphere. Also, political influences must be eliminated.

REFERENCES

[1] "Laws and Regulations Decree", Environmental Protection Agency, December 12, 2010 of http://www.epa.gov/espanol/leyesreglamentos.htm

[2] Karamouz, M, Moridi, A. and Nazif, S. "Urban Water Engineering and Management" *Taylor and Francis Group*, 2010.

[3] Walker, Roger, "Water Supply, Treatment and Distribution", *Prentice Hall Inc*., New Jersey, 1978.

[4] McGhee, Terence J, "Water Supply and Sewerage" McGraw-*Hill, Inc*., United States, Sixth edition, 1991.

[5] Consent Decree Civil Action United State District Court, Civil Action No. 10-1365. Appendix F, 2004.

[6] "Material Safety Data Sheet, GC 8791", *Gulbrandsen Technologies*, 2011.