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Application of Six-Sigma Methodology in Effluent Treatment Plant

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***Abstract*- Six sigma concept was first initiated and applied by Motorola in 1980s for their manufacturing quality improvement purposes by reducing defects in their manufacturing products to few parts per million. Since then six sigma has been applied and adopted by many service as well manufacturing and financial sectors. Looking at the present environmental condition of the world, it is very much important to put due interest in the treatment of waste or effluents generated by human activities. In this paper it is focused to improve the final treated effluent quality of an oil refinery situated in Assam, India. In this work Six-Sigma methodology (DMAIC) was applied in the Effluent Treatment Plant to reduce the Phenol ppm in the treated effluent. Moreover, it is tried to achieve the 15% Phenol betterment which was a departmental KPI in the organization for the plant. The company had commissioned a new Wax plant in 2014 and after few days of commissioning of the plant it was observed that the phenol in the treated effluent crossed the MINAS (Minimal National Standards) limit provided by the Central Pollution Control Board of India. This situation prevails for quite a long time and the company has to bear extra cost in re-cycling and diluting the final treated water. In that situation a decision needs to take to go for up gradation of the Effluent Plant Technology. Before going to major technological up gradation a Six-Sigma project has been under taken by us to help the decision making process. The outcome from the Six-Sigma project was surprising and reveals that the existing technology is adequate to handle the situation and no major up gradation needs and thereby may save a major investment.**

Keywords— Six Sigma, Process Capability, MINAS, DMAIC, DOE, RSM.

I. INTRODUCTION

Six sigma is a rigorous, focused and very highly effective implementation of proven quality principles and techniques. Six sigma virtually aims for error-free business performance. The main focus of six sigma, like many other quality initiatives, is on cost and waste reduction, yield improvement, capacity improvements, and cycle-time reductions [2]. Heavy emphasis is on satisfying customer's needs. Sigmaσ is a Greek alphabet which is used by statisticians to measure variability in any process. A company's performance is measured by the sigma level of their business process. In six sigma, a variety of statistical and scientific tools and application are used to measure and monitor the performance of the manufacturing and business process. A six sigma project consists Champions, a black belts, a black belts, green belts, process owners such as engineers who are directly involves in the process.

Six sigma methodologies comprises of phases in execution of process which are Define-Measure-analyze-improve-control (DMAIC) [1]. Many of the organizations implements define-measure-analyze-design-verify (DMADV) or identify-design-optimize-validate (IDOV) in six sigma methods for developing new process or product [1]. In application of six sigma program, the process capability is a measure of the current state of the process and it indicates the variability or spread of the process conformity. For some processes, shifts in the process average are so common that such shifts should be recognized in setting acceptable values of Cp [2].Normally shifts in the process average of ±1.5 standard deviations (of individual value) are not unusual.

Effluent treatment process now a days, are very critical to the environment and for sustainability of an industry. The environmental laws and regulation are going very stricter with the development of economy of a country. Likewise the waste or effluents treatment process technology is also going better and better to conform the specification given by the government of a country. With the increasing industrialization and intra industrial expansion, effluents characteristics are getting more and more complexity, which intern increases the cost of waste of effluent treatment process.

The described project in this paper was carried in a 3.00MMTPA Oil refinery in Assam, India with a view to improve treated effluents quality. The company has commissioned a new Wax plant in December 2014. With this expansion it was observed that the effluents generated by the refinery gets deteriorated and the Phenol content in the treated effluents got abnormally high which was consistent and the company has to bear extra cost in recycling and diluting this to make it within acceptable limit. Therefore, in this situation it was a need for the company to upgrade the existing technology by undertaking an up gradation project, which may costing a millions rupees or to upgrade the existing process. In this situation opportunity has been taken and a six sigma project was carried out in order to make a decision whether the existing facilities and technology are adequate or should go for an up gradation project with high cost.

In this paper we shall discuss detail steps we followed. In this project we have applied an amalgamated approach of DMAIC and DMADV methods. Below figure represents the relationship of these two methods.

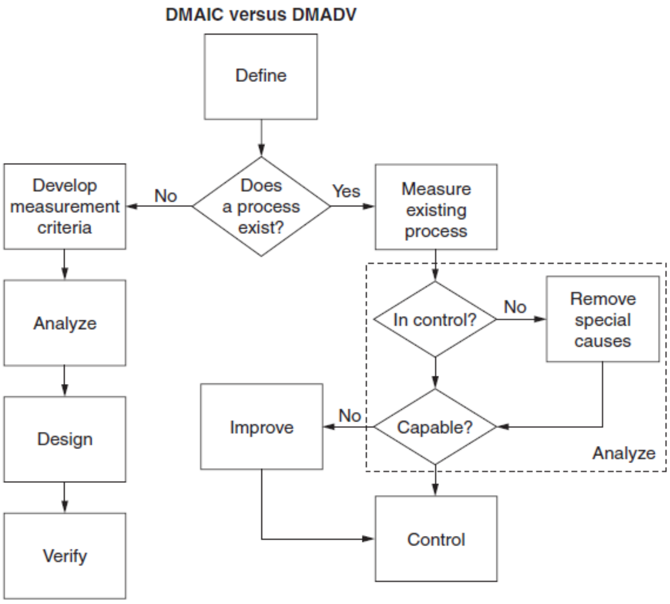

Fig -1: DMAIC and DMADV [3]

In this work emphasis was given to improve process capability (Cp). Process capability analysis is concerned to evaluate a process's ability to produce products or services that meets specifications [4]. This ability is measured by the process capability indices (PCIs). The effluent treatment plant in the company was a huge plant with a combination of 220 m3/hr Oli Water Sewer (OWS) and 110 m3/hr Contaminated Rain Water sewers (CRWS) treatment chain. All the canteen and sanitary system (C&S) and township sewage (TS) is also treated in this systems together with cooling tower blow down (CTBD) and other sewages. The plant comprises of several processing stages. But unfortunately only few parameters has been analyzed and recorded. With the recorded and available data the existing process was measured and evaluated. The plant comprises of four sections in the OWS system namely Physical Separation System, Physico-Chemical section, and Biological System and Polishing system. For the process conformity the Biological section is very much sensitive.

With this limitation, many statistical tools and many small changes in plant hardware has been carried out to improve the process capability and the sigma level of the process. The process flow block diagram is shown in the Fig: 2.

II. APPLICATION OF SIX SIGMA

The implemented six sigma project in DMAIC cycle shall be discussed here step-by-step.

A. DEFINE

In a six sigma project, the very beginning step is Define phase of DMAIC cycle. In this phase the objective of the project is to define and which to be studied and improved or rectify. It start with the process understanding. For this purpose process flow diagram prepared and the process operation manual referred extensively. To find out the problem in the defined step, all the parameters available from the Quality Control department has been collected and analyzed. From the analysis it was observed that all the parameters mean conforms to the specification limits (pH=6.0-8.5, Oil & Grease<5 ppm, COD<125ppm, TSS< 20 ppm, phenol<.35 ppm) given by CPCB except phenol. The mean of the phenol content is 0.350776 ppm which is above the

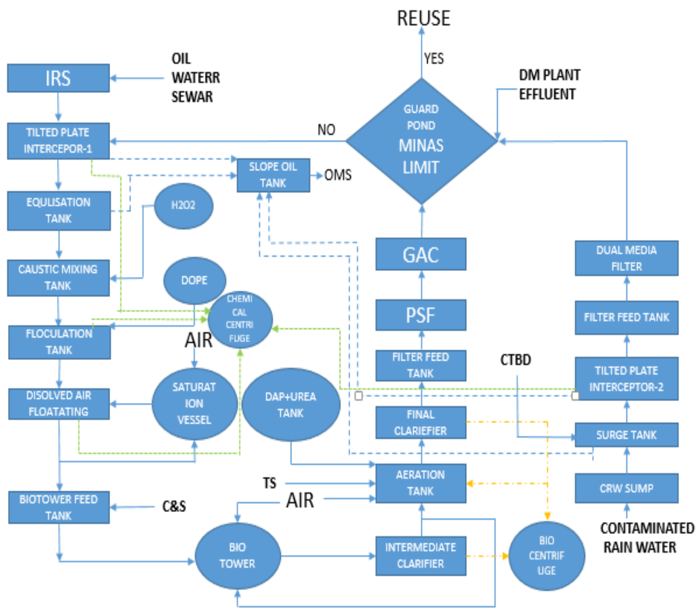

Fig-2: Process Flow Diagram

upper specification limit. Moreover, 15% phenol betterment is a KPI (Key Performance Index) for the department. Therefore, in this situation the problem is defined as the phenol content not meeting the specification of the limit.

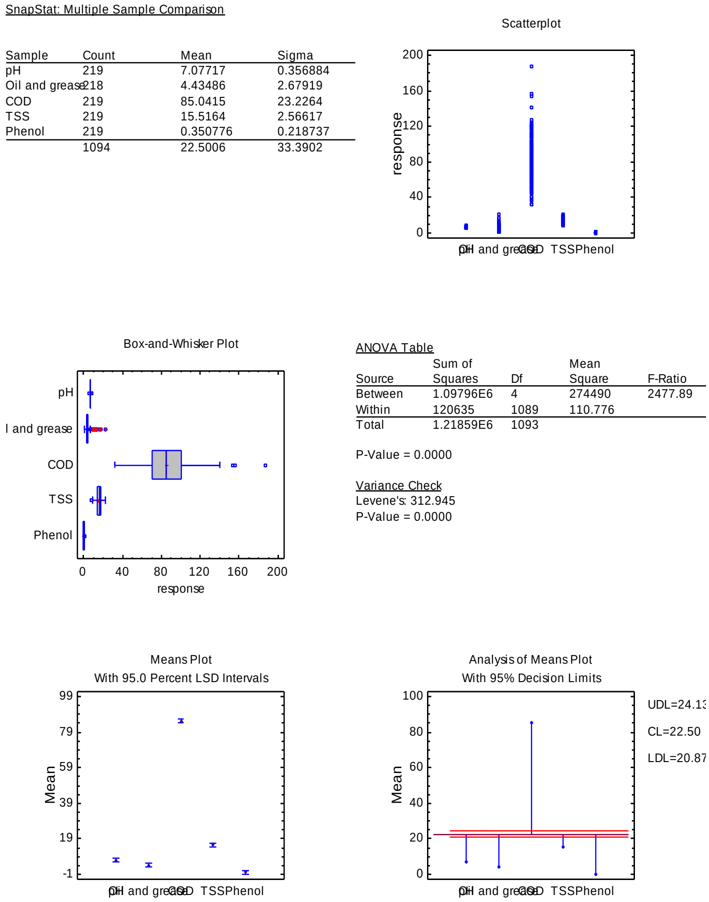

Fig-3: Analysis summery of the treated effluent's parameters.

B. MEASURE

The objective of the measure phase in six sigma DMAIC cycle is to define the existing process and to measure the level of the current state of the process. For this phase run chart was plotted for the problem mentioned earlier in the Define phase. From the run chart it is clear that the process is not capable to conform specification limit from the observation no 105 onwards continuously which corresponds to date 18.12.2014 and phenol content was 0.94 ppm.

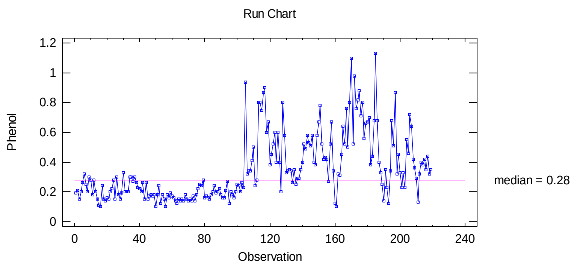

Fig-4: Run chart of Phenol content from 01.09.2014 to 26.04.2015.

It is known that a process plant (Wax Plant) in the refinery was commissioned and taken in production line from 14.12.2014. Therefore, it was assumed that the Effluent Treatment Plant process got hampered due to the deteriorated influents characteristics contributed by the wax plant.

C. ANALYZE

In the Analyze phase the problem was analyzed thoroughly by calculating the process capability. On the basis of Measure phase to compare process capability, it was evaluated in two scenarios, i) before Wax plant and ii) after Wax plant scenario. Taking observation no 105 in the run chart i.e. 18.12.2015 as a demarcation in the process and capability was analyzed in these two scenario i &ii.

i. Before Wax Plant

The collected data was statistically analyzed and I-MR chart for Phenol content was plotted. The I-MR chart is shown below.

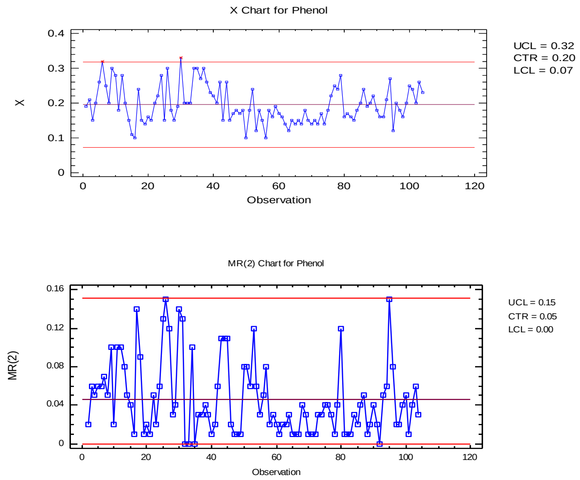

Fig-5: I-MR chart for Phenol from 01.09.2014-17.12.2014

The I-MR chart reflects that the process is in stable state and in statistical control. To estimate process capability various distributions for phenol has been fitted. From the statistical analysis the best fit is found to be Birnbaum-Saunderswith Maximum Log-Likelihood test value 162.181 and Kolmogorov-Smirnov goodness of fit test statistics 0.0862. The process capability analysis summery is shown below.

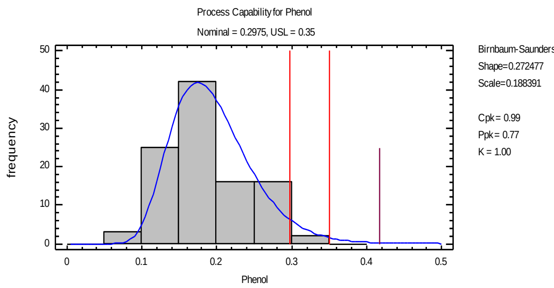

Fig-6: Process Capability Analysis.

The process capability indices Cpk=0.99 and Ppk=0.77 with Z-score=2.31. The estimated Sigma level of the process before the Wax plant is 3.81 and DPM (Defects per Million) =10449.

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ii. After Wax Plant

Likewise, process capability for the ii scenario has been estimated and capability indices are Cpk=0 and Ppk=0 with Z score=0 and sigma level of the process is 1.5.

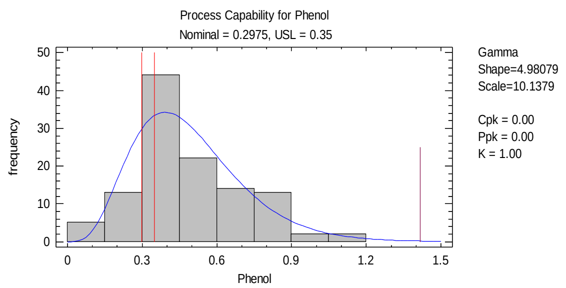

Fig-7: Process Capability Analysis after Wax Plant.

Comparison of Process capability indices are given below.

Capability Indices	Before Wax	After Wax
Cpk	0.99	0.00
Ppk	0.77	0.00
Z-score	2.31	0
DPM	10449	501350
Sigma Level	3.81	1.5

Table-1: Comparison of Process Capability Indices

The comparison clearly indicates that the process was not capable to meet the specification limits after commissioning of the new plant. Therefore, emphasis was given to short out the probable potential causes and scope in the process so that the process can be make capable irrespective of the deterioration on the influents quality by the plant. It was assumed that without any major technical up gradation the plant can handle deteriorated influents irrespective of the effects on the influent by the newly commissioned plant. For this purposes brain storming season was carried out to sort out the probable causes and their related effects. Based on the outcomes from these brainstorming seasons a cause-and-effect or fishbone diagram was created to represent the relation of the major and minor effects with their causes.

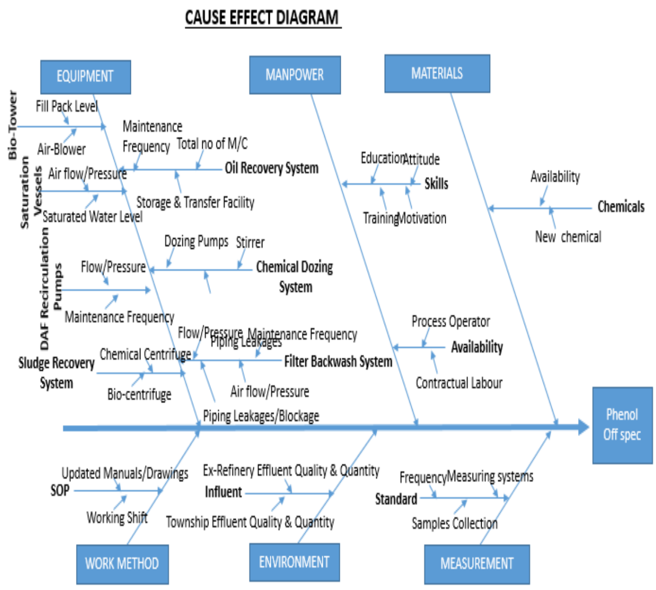

Fig-8: Fishbone diagram Phenol.

Based on the cause-effect diagram few action plans has been prepared. The major phase of the process chain for Phenol removal for the plant is the activated sludge phase. The activated sludge composed of many useful bacteria. This activated sludge is generated and taken care in the Aeration tank and Final clarifier. For the activated sludge handling phase we have conducted DOE (Design of Experiment). For DOE RSM (Response Surface Method) was applied to find out the optimum combination of external inputs. For RSM DO (Dissolved Oxygen) and the dosed chemicals DAP+UREA per day is taken as independent variable and Phenol in the treated water after polishing section taken as the response. During the experiment, two time filter backwashing operation in A and B shift and 100% recirculation of the activated sludge from the final clarifier has been taken as standard practice. The results of the experiment are given below.

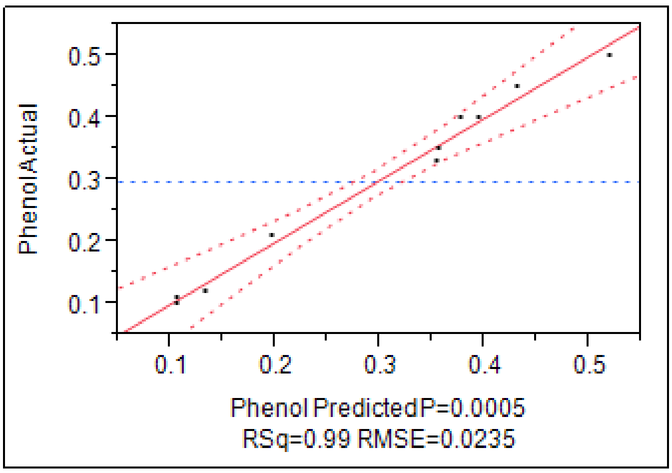

Fig-9: Actual by predicted plot.

The model R-square and adjusted R-square values are 0.989 and 0.9753 which indicates that the model fits good. The effects test shows that the dosed chemical DAP+UREA is highly significant and their combine effects are highly significant.

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
DAP+Urea(2,10)	1	1	0.00601667	10.8571	0.0301*
DO(0.5,3)	1	1	0.00081667	1.4737	0.2915
DAP+Urea*DO	1	1	0.01000000	18.0451	0.0132*
DAP+Urea*DAP+Urea	1	1	0.00840000	15.1579	0.0176*
DO*DO	1	1	0.15773333	284.6316	<.0001*

The maximum desirability test shows that the optimal combination of the input parameters are DAP+UREA= 4.94 Kg and Disovled Oxygen DO=1.74 ppm.

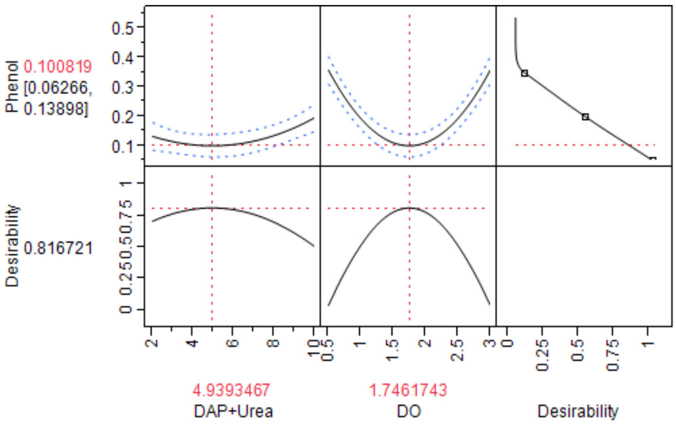

Fig-10: Prediction Profiler.

The surface plot for the experiment is shown below. The contour plots are drawn and the present operating status of the plant is known.

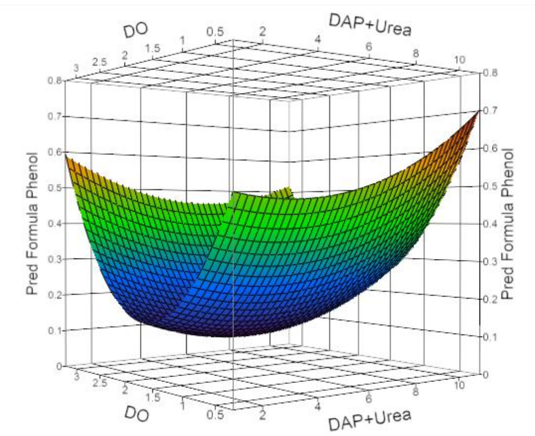

Fig-11: Response Surface for Phenol in treated effluent.

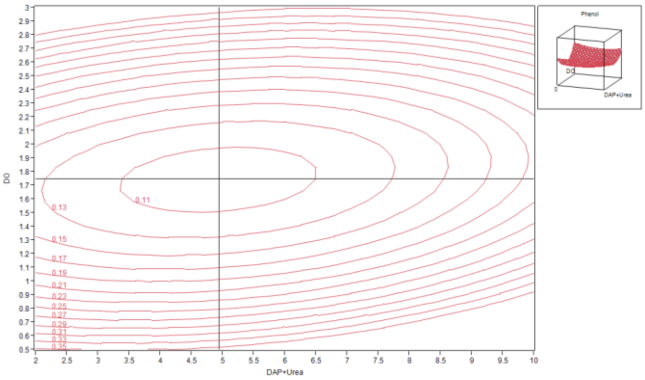

Fig-12: Contour plot for the response.

D. IMPROVE

In the improve phase the sole purpose is to apply our analysis and decisions coming out from the previous step. Based on the analysis phase's results i.e. from the cause and effect diagram and DOE the necessary action has been taken and implemented. Modification on the slop oil transfer line has been done to increase slop transfer to make the plant free oil free. The modification includes liquidity of pressure drops in the line. Along with integration of all the oil recovery system. In DAF (Dissolve Air Floatation) system the major problem was found to be the operation of saturation vessels. After thorough questing the reason for wrong operation known and the operators are duly trained at site. However, the air flow problem was seen to be present. It was eliminated by incorporating proper regulating valves in the air line. The ex-township line was extended to the inlet of Aeration tank, bio-tower was filled by packing materials. Moreover, in the polishing section, the operation philosophy was changed. Previously the filter backwashing was carried out by processed effluents and it is now carried by the DM plant effluents which are neutral and clear water. Finally the results got from DOE have been applied.

Implementing all the above actions process data collected and observed for a sufficient period. To know the impact of the results from DOE and other actions process capability study was done. The process capability indices comes as Cpk=1.00 and Ppk=0.73 and DPM=14628.7 and sigma level=3.68.

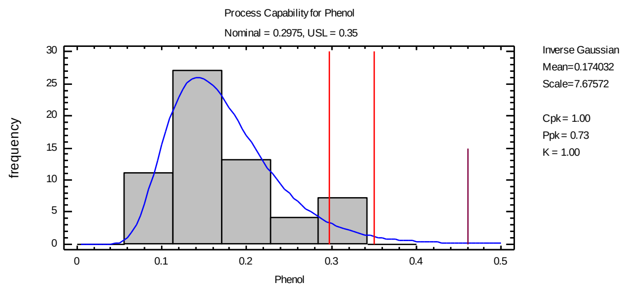

Fig-13: Process Capability Analysis to measure improvement.

The I-MR chart has been plotted as given below.

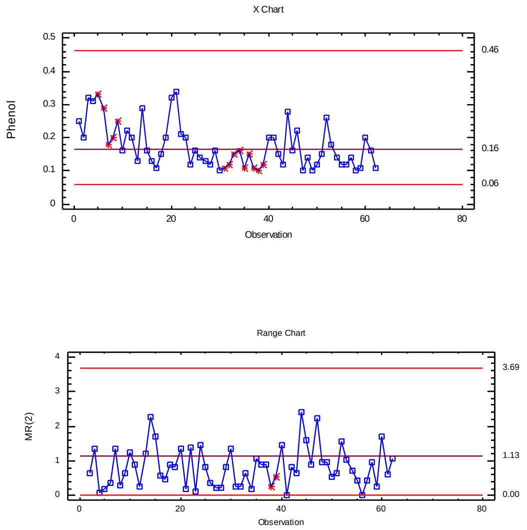

Fig-14: I-MR chart from 02.06.2015-09.08.2015.

To know the process behavior I-MR chart created corresponding to all the phases.

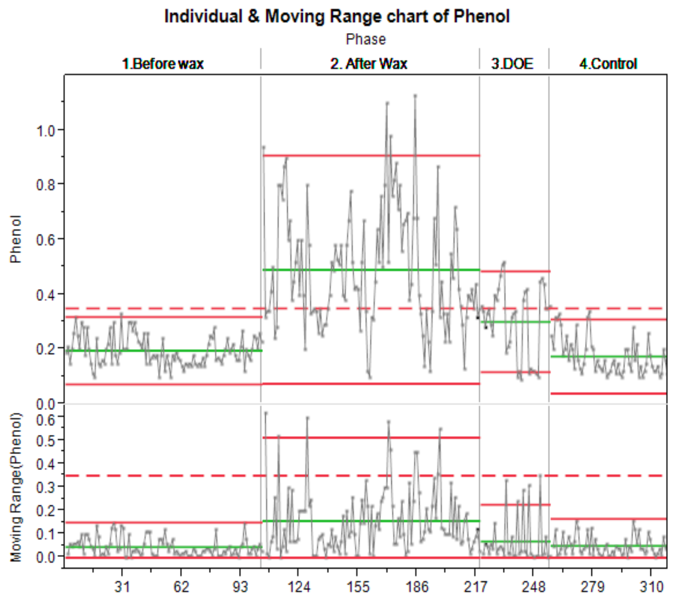

Fig-15: Phase wise I-MR chart.

Comparing the process capability indices it is seen that the process becomes stable and statistically controlled with significant improvement.

E. CONTROL

In the control phase of DMAIC the purpose is to maintain and control the improved process. For this purpose data collected from the daily laboratory report published by the Quality Control Department and run chart has been prepared. The process is strictly monitored and necessary corrective actions taken to adjust the process when there is a chance of upward trend.

III. CONCLUSION

From the study it is seen that Six-Sigma is a proven and well and good methodology for quality improvement purpose. It is seen that after application of Six-Sigma the process variability reduces and thereby reduces the quality cost. From this study it may be concluded and accepted that the existing technology in the Effluent Treatment Plant was suitable and adequate to perform well in the Refinery configuration. Though minor modifications are needed for the adjustment of the process the company may save a huge amount of investment or expenditure instead of upgrading the existing plant or by going for new technology.

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REFERENCES

[1] “Six sigma methodology in improving assembly yield of high-power and high brightness light emitting diodes packages for automotive application”, 33rd International Electronics manufacturing Technology Conference 2008. Law, Zhang, Kmetec, Wall, Chan and Koay.
[2] “Juran’s Quality Handbook” Fifth edition, Joseph M. Juran and A. Blanton Godfrey, McGraw-Hill, ISBN: 0-07-034003-X.
[3] “The six sigma handbook, A complete Guide for Green Belts, Black Belts, and managers at all levels”, Third edition, Thomas Pyzdek & Paul Keller. McGraw-Hill, ISBN: 978-0-07-162337-7.
[4] “A Bibliography of the Literature on Process Capability Indices: 2000-2009”, Yum and Kim, Quality and Reliability Engineering International, July-2010, Wileyonlinelibrary.com,DOI:10.1002/qre.1115