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The Role of Six Sigma Quality in the Powder Product Enhancement at a Leading Saudi Fertilizers Manufacturing Company

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***Abstract*— a leading Saudi fertilizer manufacturer faces challenges in the quality consistency of its powder products due to chemical composition heterogeneity. This issue stems from variations in product configurations, leading to unstable chemical compositions and standard output. This paper aims to enhance powder product quality by reducing defects and inefficiencies through the application of Six Sigma methodology. Process control charts allows the testing of corrective techniques, in order to eliminate problems and achieve the goal of no malfunctions or errors in the process. The Six Sigma process applied for the blend ratio has reduced the number of non-conforming products. The numbers of non-conforming products have been reduced from around 583 K to 56 K ppm.**

***Keywords*— Six Sigma, Quality Control, Powder Fertilizers, Process Optimization, Chemical Heterogeneity.**

I. INTRODUCTION

Powder fertilizer products manufactured by Saudi Fertilizer Company are critical for agricultural productivity in Saudi Arabia. The aim of this research is to standardize powder products. Six Sigma process are used to improve the production. This paper tests the factors that affects the quality of powder fertilizer products manufactured by a Saudi factory and try to standardize the blending ratio.

Farmers purchase powder fertilizers from the case factory in order to increase vegetables and fruits yield. The properties of the powder fertilizer of the case company:

- Contains a physical blend of many needed minerals.
- Packaged in different bag sizes.
- Can be customized as per the client's preferred mixing ratio.

Collected historical data for the blend ratio and the Variances of such ratio is available in the company databases.

The influencing factors that affects the manufacturing of the blend ratio are:

- Raw materials; raw materials is provided by different suppliers; as an example potassium nitrates is supplied from Jordan and China. Jordanian potassium nitrate is more filtered than the Chinese variants.
- Equipment's; different mixing and conveying equipment's used to complete the product. Equipment's may also yield a metal particles in the product. Contamination may also be viable.
- Process; physical versus chemical blending.
- Measurement; defected and not calibrated tools.
- Environment; temperature, humidity, illumination, etc.
- Personnel; Day versus night shifts.

This Paper aims to standardize the blend ratios of powder fertilizer produced by the case company through:

1. Collecting random data on the blend ratios.
2. Search the literature and the expert's opinions on the root causes by drawing a fish bone diagram.
3. Reduce the variances in the blending ratios. This considers changes of the influencing factors and re-measuring the ratio Variances due to the changes. Minitab statistical software is used.

The clients are complaining on the blend ratios being varied from specifications. This paper investigated the problem by collecting and measuring of such finished product blend ratios. Afterwards, the process is analyzed through a proper variable chart to track the assignable causes. The analysis is also made by interviewing the process engineer on the causes of such problems. An attempt to improve the process by adjusting the setting is made.

In the case factory which produces a physical blend of Nitrogen, Phosphate and Potassium (NPK) 20-20-20, the causes of defects in the production is the incompatibility of the chemical composition in the final product.

Fig. 1 below explains the process made in the case factory. The compositions of the blend are unloaded separately. Each material is crushed and then weighted in the volumetric scale. The material is then sent to the bed mixer which awaits the other components to be mixed inside it. Once the composition is completed and mixed in the bed mixer the composition is sent to the filling machine.

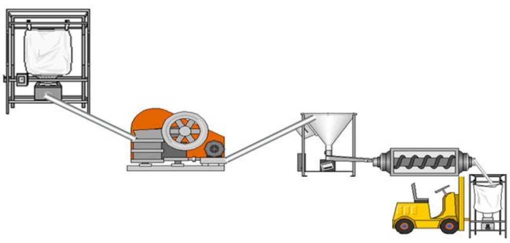

Fig. 1. Production process at the case factory

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The Urea raw material, is one of the reasons that cause problems in the chemical composition in the final product due to its melting characteristics inside the production line, causing adhesion of materials inside the line, it is suggested to replace the urea with urea phosphate because of its physical properties that resist climate fluctuations and its lack of solubility inside the line. Urea Phosphate reduces the molar values of urea compared to phosphates. Another reason for the incompatibility of the chemical composition in the final products is not giving enough time for mixing the materials inside the powder mixer.

The Raw materials are purchased from several sources such as Jordan, China, Russia, or factories inside Saudi Arabia.

Potassium sulfite is purchased in large quantities and placed in a warehouse. It is used with the materials inside the line in order to take 50% of potash.

At the packaging stage, a sample of the product is withdrawn for NPK 20-20-20 product mix. In the analysis process, the chemical composition of each compound must not exceed the permissible tolerance limits.

The tolerance limits are as follow:

- The allowed nitrogen is 20+- 5% (19-21)

Accordingly, the Improvement processes to reduce or eliminate defects are;

1. Replacing raw materials with materials that are compatible with the Environment.
2. Giving enough time in the process of mixing before transferring them to the packaging stage.

Random Samples are taken by the laboratory at different times, such as when each pallet is finished. Each production process for each product carries three pallets. Each pallet contains 45 bags, each bag holds 20 kg. The production capacity of the powder line is 2700 tons per day. Many rejection reports for NPK 20-20-20 product due to the dropping of nitrogen percentage.

Quality is the ability to produce goods or services that match the needs of the final customers, while matching with the specifications limits stated by the business firm [1]. Goods produced in a high quality helps generally in gaining loyal customers and enhance the company public image. Customers do share their experiences regarding a company product with their friends and relatives. A manufacturer of a good quality has lower competition when being compared with another company that produces lower quality products [2].

- Quality in Powder Fertilizers

One of the most important problems facing the fertilizer industry is that fertilizer tends to clump during transportation and storage. Solidification occurs through interactions at contact points formed between solid fertilizer particles. These interactions, also called contact mechanisms, are activated by different fertilizer properties and environmental conditions. Prevention of caking mechanisms directly affects the quality and financial value of the final product and is an important research topic to ensure its applicability. Good quality fertilizers are easy to apply in agriculture and have a direct impact on plant nutrition and crop productivity. At present, there are various promoter practices for maintaining fertilizer fluidity, which can be maintained or suggested during or after production, both in industry and in research and development. To develop new process control points in industry, it is important to understand the factors that cause caking and the mechanisms of physicochemical interactions that proceed with them. In addition, it is important to improve the storage conditions of fertilizers and maintain their quality until final use. This paper examines the caking behavior of fertilizers in detail and provides brief information on anti-caking and different types of anti-caking agents [3].

- NPK Fertilizer for Agricultural Use

In conclusion of their study, the foliar application of nano-chelated NPK 20-20-20 fertilizer in norm 800 or 1200 g/ha was found to be optimum for crop growth, yield and concentration of nutrients in grains and increases the agronomic efficiency [4].

- Quality Tools

A. Ishikawa Diagram

The cause and effect diagram is an analysis tool which provides a framework for showing the influencing factors which causes the problem [5]. The fishbone diagram is named after a Japanese quality control statistician who is named Kaoru Ishikawa. The name fishbone describes the structure and the appearance of the diagram. The following are the advantages of the diagram:

1- Configure relationships: The fishbone diagram shows the possible sources of the problems.

2- Summarize causes of the problem in short time: the diagram shows the underlying causes that need to be investigated.

3- Emphasize the importance of brainstorming: The categorical classification of the fishbone diagram enables for more arranged structure.

4- Helps in keeping team shared thoughts: The structure developed helps on focusing on special type of data.

[6] and [7] suggested that the cause-and-effect diagram is an effective tool for six sigma applications since it engages a degree of importance while discerning causes of problems in business processes. This paper details that these business improvement processes employ basic quality management tools such as the fishbone diagram, Pareto chart, and the I-MR control chart.

B. I-MR Variable Control Chart

Stated by [8], that there is many times in which the sample size for a process monitoring equals to 1. In such situations the control charts for individuals units is useful. [6] reasons that the I-MR control chart or the Shewart Charts are advantageous when the data is continuous.

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II. METHODOLOGY

A. Research Steps

This Paper strives to make assure that the quality of NPK Fertilizer in terms of Nitrogen composition is under statistical control.

This Paper steps are as below:

1. Interview the Fertilizer Factory Process Engineer of the factors affecting NPK Fertilizer quality.
2. Draw a Fishbone Diagram for the Root causes variation in the Nitrogen Composition. Thus, the root causes shall be categorized under the following main causes:

A- Man: This may include the characteristics of the operator and the workers, including their experience levels, knowledge, behavior, perceptions, attitudes, etc.
B- Machine: This may include the characteristics of the equipment's in the production line, including their Age, maintenance jobs, operating procedures, manufacturer, technology used, etc.
C- Environment: This may include the characteristics of the surrounding Environment, including the humidity levels, temperature, wind direction, wind speed, etc.
D- Materials: This may include the characteristics of the raw materials, including the density, source, storing conditions, etc.
E- Process: This may include the characteristics of the process itself, including the sequence, settings, operating procedures, etc….
F- Measurements: This may include the characteristics of the Measurement methods employed, including the scale type, calibration, etc.

3. Collect Data Samples for the Nitrogen composition at each run. Thus, sample size equal to 1 and shall be taken for 209 runs.
4. Construct an Individual Moving Range control chart and plot the data.
5. Decide whether the Process is under Statistical Control. Accordingly, we could say that the runs are being under statistical control, while Recommendations shall be based on the Fishbone Diagram sourced from the expert engineer point of view for the causes.
6. Calculate and plot the process Capability.
7. Conclusions and Recommendations for the improvement on the process based on the constructed fishbone diagram.

B. Root Causes Affecting Nitrogen Composition

This Paper shall start by interviewing the production engineer of the fertilizer factory regarding the factors affecting the Nitrogen Composition in the product. The following root factors may affects the Nitrogen Composition:

1. Process Violation. (Man)
2. Laziness in checking and adjusting. (Man)
3. Low Accuracy. (Machine)
4. Old Technology. (Machine)
5. Raw material composition Modification.(Urea Compounds)
6. Constant Texture. (Materials)
7. Increase the line speed.(Process)
8. Change in the mixing parameters.(Process)

Fig. 2 below shows the roots causes of declined Nitrogen Composition in the finished product. The root causes are categorized under the following categories:

1. Man.
2. Machine.
3. Process.
4. Materials.

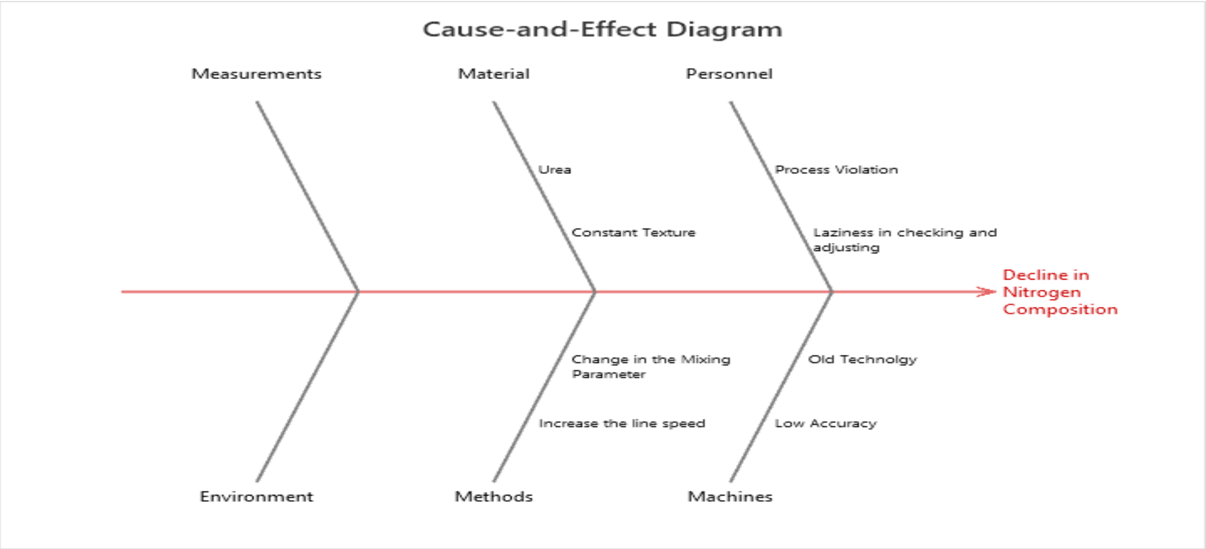

Fig. 2. Fishbone Diagram for the Root Causes of Decline in Nitrogen Composition

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C. Data Collection and Analysis

Individual reading was collected for 209 days and are analyzed using Minitab statistical software. I-MR chart was chosen because it is the variable control chart that is proper for monitoring Individual readings in a sample. See Fig. 3. Thus, no point was outside 3.00 standard deviations from center line. Namely, no point was outside the upper and lower control limits and no trends were occurring. The data showed that the process is under statistical control. No trend was observed. For the control limit of the Individuals, the upper control limit value is 22.332, the Mean is 19.584 and the lower control limit is 16.835. The Moving Average control chart has a maximum difference between two sequential samples of 3.376, a mean difference of 1.033.

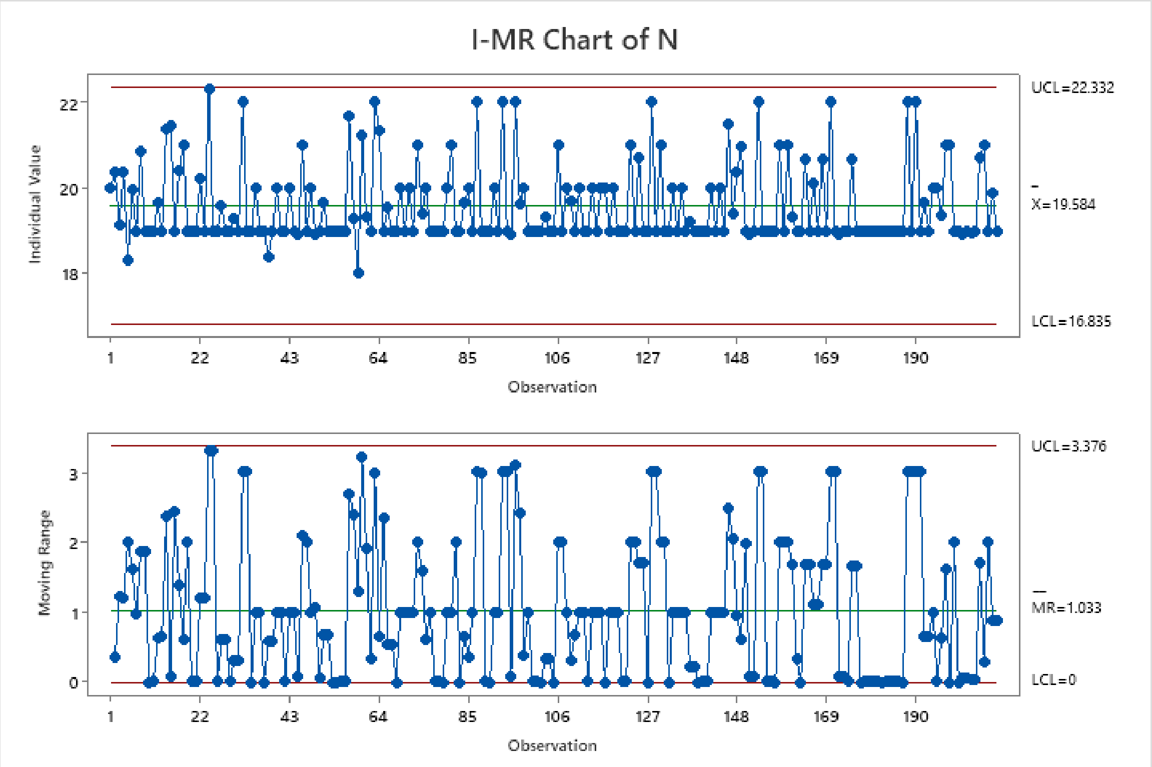

Fig. 3. I-MR Chart for Data Gathered

Based on the plotted I-MR control chart, the lower control limit of Individual readings is 16.835 of Nitrogen Composition is considered low. This problem may be solved by the interpretation of the drawn Fishbone diagram as:

1. Composite Modification: The ingredients of the urea melts with the mix causing bad mixture. The Production Engineer advise in changing it with Urea Phosphates that doesn’t melt during products mix.

2. Reduce of the process line speed: To solve the Nitrogen depletion problem, it is recommended to speed up the line speed.

3. Old Machine Technology: To overcome this problem, it is recommended to use a gravity based technologies to enhance the production speed and to reduce jammed Urea.

- Process Capability

However, Lower and Upper Specification limits is found for the product, having the upper specification limit set at 21 and the lower specification limit sets at 19. The data was analyzed through Minitab statistical software for the for the gathered sample.

Fig. 4 shows the output result for the process capability analysis. Thus, due to having an upper specification limit and no lower specification limit then CPu=Cpk. The results shows that CPu=0.52 and <1.33. The results indicate that the process is not capable of producing parts within the specifications.

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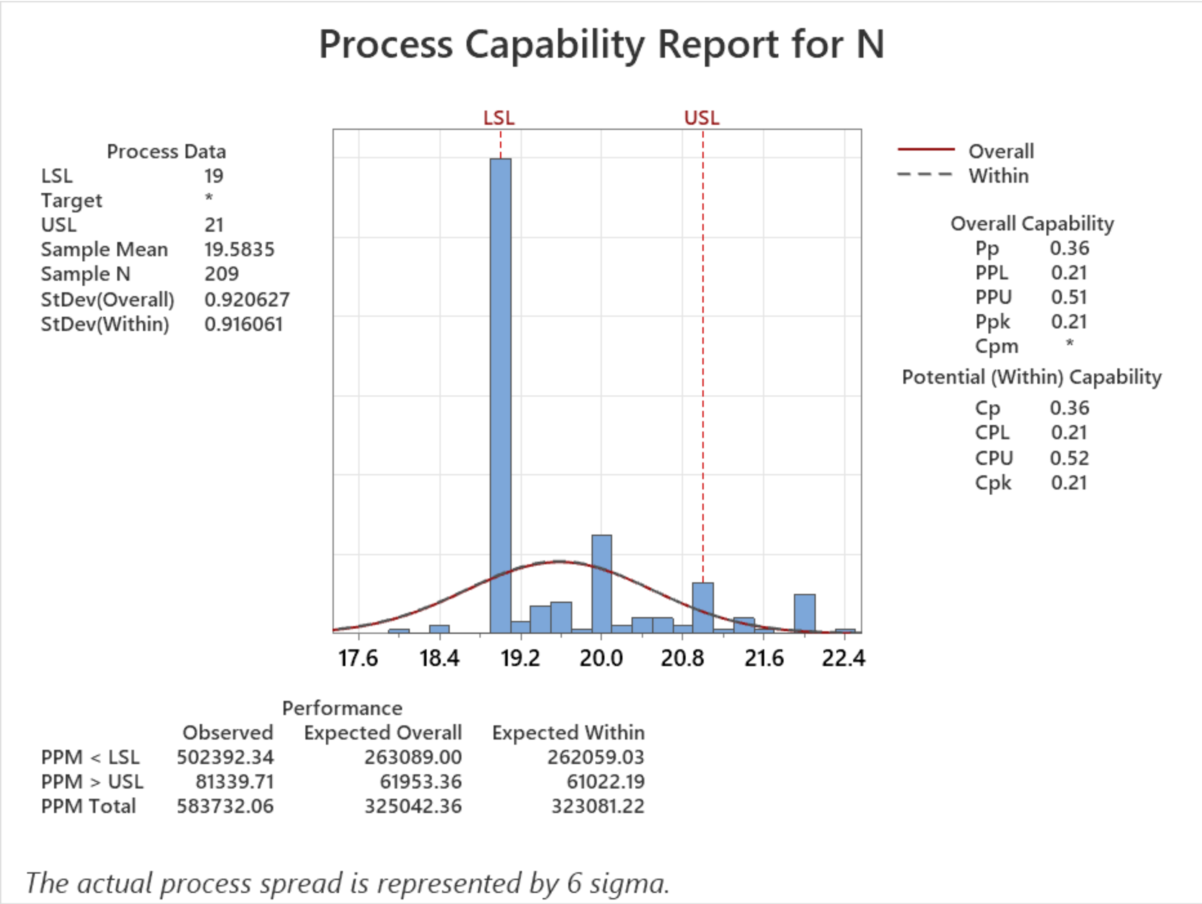

Fig. 4. Process capability of Nitrogen Composition of The NPK Fertilizer Product

- Six Sigma and Fertilizers Manufacturing

The target of Six Sigma is to reduce process variation, while trying to improve the process. Six sigma starts by defining the process. The processes involved in production of the NPK Fertilizer including; the compositions of the blend are unloaded separately. Each material is crushed and then weighted in the volumetric scale. The material is the sent to the bed mixer which await the other components to be mixed inside it. Once the composition is completed and mixed in the bed mixer the composition is sent to the filling machine.

NPK 20-20-20 Fertilizer customers complains about some of the products purchased has a low composition of Nitrogen.

Stated by [9], that a perfect Six Sigma level is implemented, in case there are no more than 3.4 defects in the process per million. The process capability analysis has showed that there is a potential of 502,392 products per million do not conform to the minimum specification.

At this stage, possible defect sources are being discussed per the following categories:

1- Methods: the composition is physically mixed without the presence of water that is used to balance compounds in the chemical blending process. Therefore, it is recommended to use chemical blending and have evaporation and drying technologies (Costly Solution).
2- Environment: The humidity of the warehouse is high because of being located near to the seaport. When the mixing is done, humidity can cause product mass shrink. It is recommended to install dehydrators in the production site.
3- Raw Materials: Replacing Urea with Urea phosphates.
4- Human errors: It is observed that the workers didn’t manage the unloading of the Raw Materials.
5- Measurement: The ratio of compositions shall be balanced accurately while mixing.
6- Equipment: The Urea may stack in the extruder while mixing. The mixer shall have high speeds to dry the humidity in the mix.

After implementing the recommended measure of replacing the Urea by Urea phosphates, Data are gathered for the Nitrogen composition.

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After revising the graph of I-MR chart, no point was outside the control limits for the process and the variables. The data showed that the process is under statistical control. See Fig. 5 below.

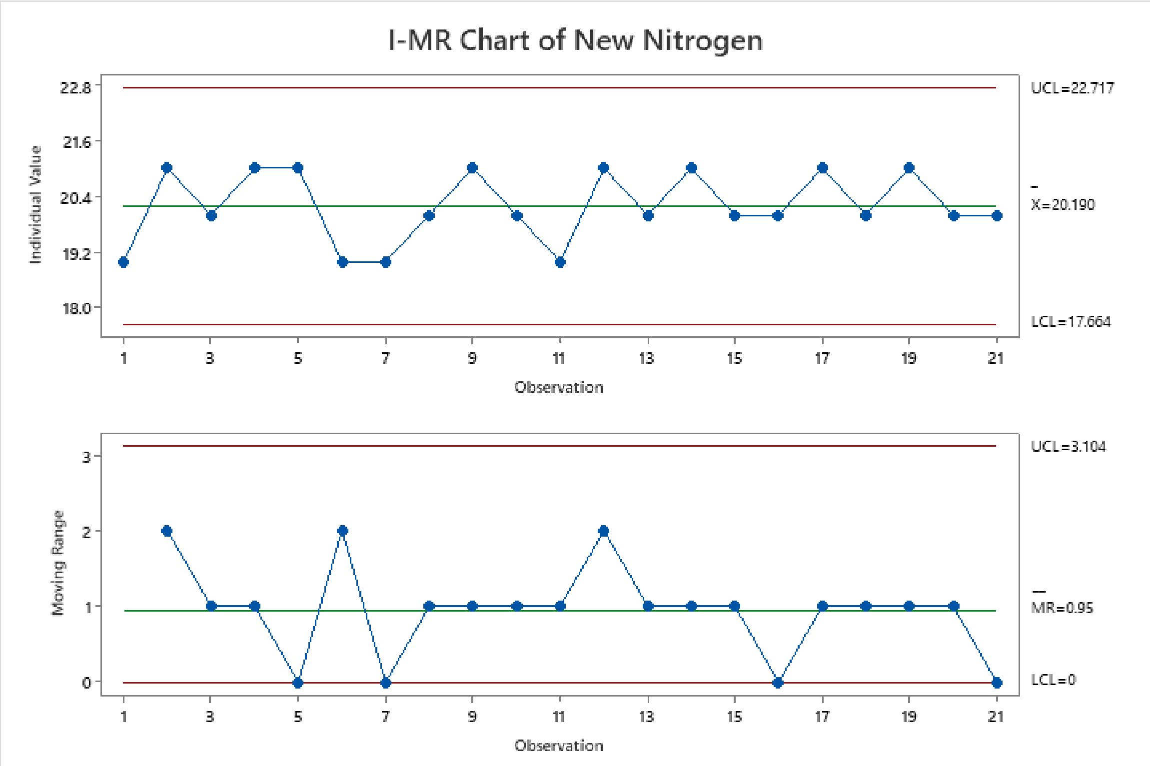

Fig. 5. Individuals Moving Ranges for the Nitrogen Composition after Replacing Urea by Urea Phosphates.

After revising the graph of the specification limits, the process capability analysis has showed that there is a potential of 56,127 products per million do not conform to the minimum specification. This has dropped from 502,392 products per million. See Fig 6.

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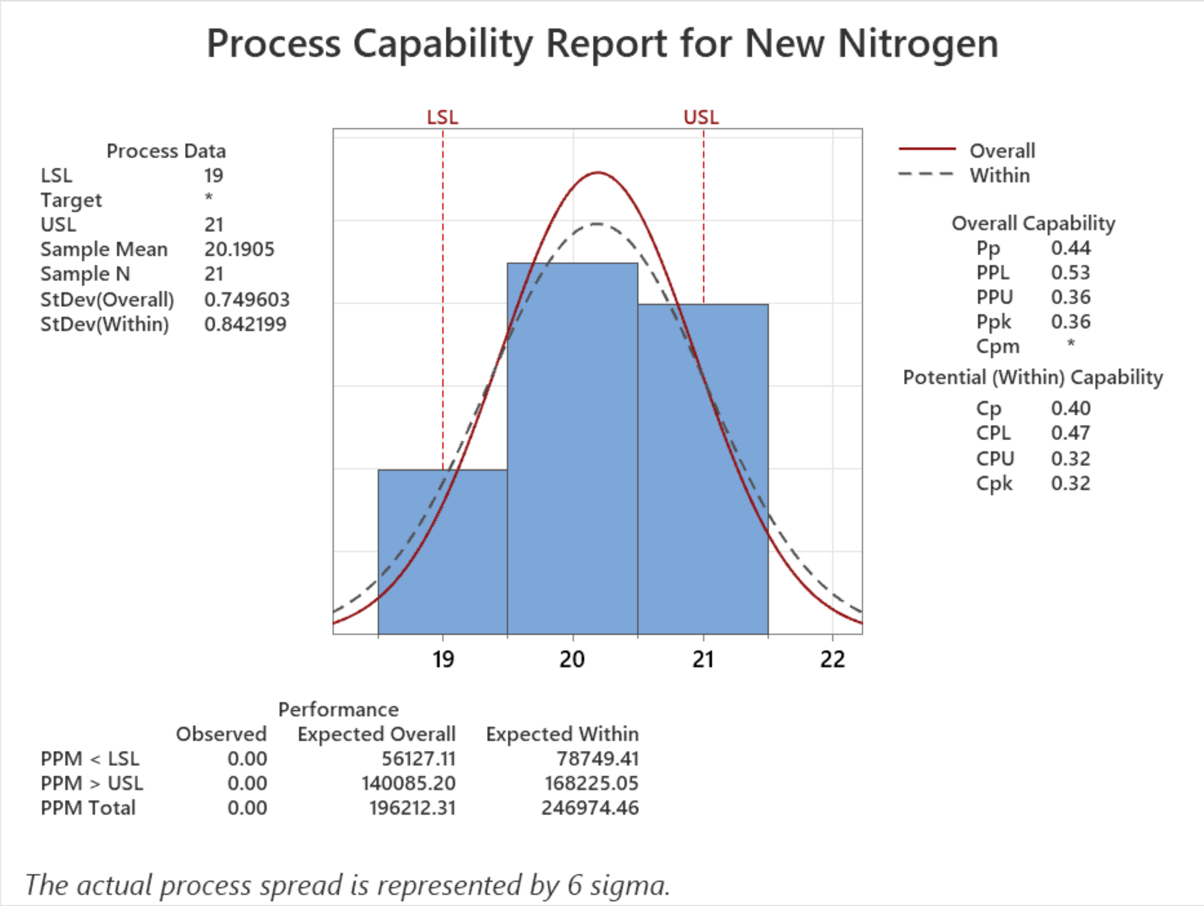

Fig. 6. Specification Limits after Replacing Urea by Urea Phosphates.

III. CONCLUSION AND RECOMMEDDATIONS

Saudi Fertilizer Company has problems with powder products, as differences in chemical composition occur. One such problem is the heterogeneity of materials in the production line. The reason for this is the difference in product configurations resulting in lower quality of products. When performing chemical analyzes, the instability of the chemical composition of each product. The aim of this Paper is process improvement and improvement of powder products, defects and inefficiencies. Six Sigma can be applied to quality management in powder products. To get the job done, Six Sigma is being used for process improvements. Process control charts would allow to monitor and track changes ing the process.

The main goals of this paper are to investigate the root causes of producing non-adequate NPK ratio products.

Some recommendations was made for the reduction of such problems.

This paper has analyzed the data gathered regarding the non-adequate NPK ratio products. Variation in the NPK ratio may harm the company reputation. Quality control aims to standardize the product and match it with specifications. After the analysis of 209 days runs on Minitab statistical control software, each sample has an individual reading, the procedure of the paper was as follows:

1- Choose the best control chart that may be used: thus, the variable control chart that may best be chosen is the I-MR Chart.
2- Plot the data using Minitab statistical software: thus, the first is to analyze the I-MR chart that represents the variability, where no point was out of the control limits. The process is considered to be under statistical control. Based on the fishbone derived from the responsible production engineer, This paper has recommended to improve the production by changing the composite (Urea Phosphate rather than Urea) and using of vertical mixers (Gravity).
3- Were the data is under statistical control and the improvement is made, to set the tolerance limit to +-1.

Six sigma processes has been implemented on the manufacturing processes. This paper has reduced the non-conforming products from around 583 K to 56 K per million.

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Conflicts of Interest: The authors declare no conflict of interest.

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